PB195145

CHATTANOOGA, TENNESSEE - ROSSVILLE, GEORGIA
INTERSTATE AIR QUALITY STUDY
1967-1968

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 2215.

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service

122

CHATTANOOGA cont.

experiments. Emissions from stationary fuel combustion, mobile sources, solid waste disposal, and industrial process losses are tabulated.

KEY WORDS: Interstate Air Quality, Tennessee, Georgia, Air Pollution, Valleys, Chemical Processing, Abatement, Area Survey, Vegetation

CHATTANOOGA, TENNESSEE -- ROSSVILLE, GEORGIA INTERSTATE AIR QUALITY STUDY. Grady T. Helms, James H. Southerland, Kenneth R. Woodward, Ibrahim J. Hindawi, Dale H. Coventry, and Charles D. Robson. USDHEW, PHS, EHS, NAPCA, Division of Abatement. Raleigh, N.C. NAPCA Publication No. APTD- 0583 . October 1970.

Air pollution in the Chattanooga, Tennessee -- Rossville, Georgia, area attributable to suspended particulate matter, nitrogen oxides, suffur oxides, carbon monoxide, hydrocarbons, oxidants, and acid mist is evaluated in terms of concentrations and hazard potentials in compliance with the Clean Air Act of 1967.

Meteorological surveys of temperature and wind direction and speed indicate two areas of restricted airflow and frequent inversions, one located in the downtown Chattanooga valley, and another in the valley near the Volunteer Army Ammunition Plant (VAAP). Air quality studies indicate, and emissions surveys verify, high levels of air pollution in both areas. High concentrations of suspended particulate matter are reported for both valleys. Nitrogen oxides and sulfur oxides are more concentrated near the VAAP and ammonium, nitrate, and sulfate compounds were found in high concentrations in the eastern sector, near the chemical plants.

Pollutant damage to rubber, nylon, metal, silver, dyed fabrics, and vegetation in the area is evaluated on the basis of controlled

STANDARD TITLE PAGE FOR TECHNICAL REPORTS	1. Report No. APTD-0583	2. Govt. Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

Chattanooga, Tennessee - Rossville, Georgia Interstate
Air Quality Study
1967-1968

5. Report Date
October 1970

6. Performing Organization Code

7. Author(s)
Helms, Grady T., et al.

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Division of Abatement
DHEW, PHS, EHS, National Air Pollution Control Administration
Durham, North Carolina 27701

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Agency Name and Address
Same

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstracts

In 1965, the U.S. Army reactivated the Volunteer Army Ammunition Plant at nearby Tyner, Tennessee, to produce explosives needed for defense. Shortly thereafter numerous complaints of particulate and gaseous emissions were received by various governmental officials from many irate citizens in the surrounding area. On October 1, 1967, an air quality survey was begun in the Chattanooga, Tennessee - Rossville, Georgia, interstate area to fulfill both the request of the Department of Defense and the City of Chattanooga. Four other investigations were conducted in the area during the period from October 1967 through April 1969: (1) meteorological measurements; (2) vegetation effects measurements; (3) materials effects studies; and (4) emissions survey. This report concerns these investigations and their results.

17. Key Words and Document Analysis. (a). Descriptors

Air pollution
Environmental surveys
Munitions industry
Aerosols
Exhaust emissions
Inventories
Meteorology
Vegetation
Materials
Deterioration
Wind (meteorology)
Temperature inversions
Dust
Sulfur dioxide
Nitrogen oxide (NO)
Nitrogen dioxide
Oxidizers
Hydrocarbons
Carbon monoxide
Sulfates
Ammonium compounds
Inorganic nitrates
Corrosion
Fading
Tarnishing
Nylon fibers
Elastomers
Cracking (fracturing)
Plant pathology
Fuel consumption
Vehicles
Waste disposal
Industrial wastes
Mist
Experimental data
Sulfuric acid
Nitric acid

17b. Identifiers/Open-Ended Terms

Chattanooga, Tennessee
Rossville, Georgia
Tennessee
Georgia

17c. COSATI Field/Group 13/02, 06/03, 11/

18. Distribution Statement Unlimited	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 127
	20. Security Class. (This Page) UNCLASSIFIED	22. Price

FORM NBS-867(1-70)

CHATTANOOGA, TENNESSEE — ROSSVILLE, GEORGIA INTERSTATE AIR QUALITY STUDY

1967-1968

Grady T. Helms
James H. Southerland
Kenneth R. Woodard
Ibrahim J. Hindawi
Dale H. Coventry
Charles D. Robson

Division of Abatement

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
National Air Pollution Control Administration
Durham, North Carolina
October 1970

The APTD (Air Pollution Technical Data) series of reports is issued by the National Air Pollution Control Administration to report technical data of interest to a limited readership. ~~Copies of APTD reports may be obtained upon request, as supplies permit, from the Office of Technical Information and Publications, National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare, 1033 Wade Avenue, Raleigh, North Carolina 27605.~~

National Air Pollution Control Administration Publication No. APTD-0583

ACKNOWLEDGMENTS

This study would not have been possible without the cooperation of Ralph Kelley, the former Mayor of the City of Chattanooga; D. P. Roberts, Director of the Division of Air Pollution Control, Tennessee State Health Department; and Dr. J. H. Venable, Director, Georgia Department of Public Health. The United States Army Hygiene Agency and Atlas Chemical Company also provided consultative services to the NAPCA research team.

CONTENTS

1. INTRODUCTION 1

2. METEOROLOGY 5

  2.1 Climatology 5
  2.2 Meteorological Investigations 6

    2.2.1 Wind Speed and Direction Measurements 9
    2.2.2 Inversion Measurements. 12

  2.3 Summary and Conclusions 14

3. AIR QUALITY MEASUREMENTS 17

  3.1 Particulate Pollutants. 17

    3.1.1 Suspended Particulate - High-Volume Samplers . . . 17
    3.1.2 Suspended Particulate - Respirable Dust Fraction . . . 20
    3.1.3 Suspended Particulate - Soiling Index 21
    3.1.4 Settleable Particulate - Dustfall 23

  3.2 Sulfur Dioxide 26
  3.3 Nitrogen Oxides 28

    3.3.1 Nitrogen Dioxide 32
    3.3.2 Nitric Oxide 32

  3.4 Oxidants. 36
  3.5 Hydrocarbons 36
  3.6 Carbon Monoxide 36
  3.7 Chemical Analyses of Suspended Particulate. 38

    3.7.1 Sulfate 38
    3.7.2 Ammonium 38
    3.7.3 Nitrate 41

  3.8 Summary 41

4. MATERIAL EFFECTS INVESTIGATIONS 45

  4.1 Metal Corrosion 45
  4.2 Color Fading in Dyed Fabrics 45
  4.3 Silver Tarnishing. 47
  4.4 Nylon Deterioration 49
  4.5 Rubber Cracking 50
  4.6 Summary 51

5. VEGETATION SURVEYS 53

  5.1 Indigenous Vegetation Surveys 53
  5.2 Selective Vegetation Survey 54

    5.2.1 Survey Plan 54
    5.2.2 Specific Damage 57
    5.2.3 Non-Specific Damage 59

5.3 Summary and Conclusions 60

6. EMISSIONS INVENTORY 61

6.1 Emission Source Categories 61

6.1.1 Stationary Fuel Combustion 61
6.1.2 Mobile Sources 65
6.1.3 Solid Waste Disposal 65
6.1.4 Industrial Process Losses 65

6.2 Pollutants 65

6.2.1 Particulate Matter 65
6.2.2 Nitrogen Oxides 68
6.2.3 Sulfur Oxides 69
6.2.4 Carbon Monoxide 69
6.2.5 Hydrocarbons 75
6.2.6 Acid Mist 76

6.3 Summary 76

7. REFERENCES 81

APPENDIX A. Meteorological Information 85

APPENDIX B. Air Quality Station Information 93

APPENDIX C. Frequency Distributions of Air Quality Measurements 99

APPENDIX D. Emission Inventory Information 113

CHATTANOOGA, TENNESSEE — ROSSVILLE, GEORGIA INTERSTATE AIR QUALITY STUDY
1967-1968

1. INTRODUCTION

History-rich Chattanooga is located in the scenic southeastern corner of Tennessee, situated among and spreading up the sides of Lookout Mountain, Signal Mountain, and Missionary Ridge. The metropolitan area is composed of the cities and municipalities of Chattanooga, Red Bank, East Ridge, Lookout Mountain, and Signal Mountain in Tennessee and Rossville in Georgia. In 1967, the population of Chattanooga was 135,339 while that of the metropolitan area was 292,283. Favored by low-cost TVA electric power, the area is promoted locally as the "Electrical Center of the South." Access to the navigable Tennessee River, a large local rail center, numerous trucking lines, and proximity to abundant natural resources make the area a nearly ideal location for industry, as well as a tourist attraction.

The metropolitan Chattanooga area is dominated by the Appalachian Mountain system, which extends northeast from Alabama across Tennessee as a series of parallel ridges and intervening flat valleys. The Cumberland escarpment forms the western horizon of the valley of the Tennessee River, rising 1,000 to 1,500 feet above the valley floor. Eighteen miles southeast across several lesser ridges, the White Oak Range rises 600 to 900 feet to form the eastern rim of the valley. The Tennessee River meanders southwesterly amid these topographic features from Chickamauga Lake to the base of Lookout Mountain and then loops north and west through the escarpment into another valley. Tributary creeks in the metropolitan area flow north within their secondary valleys until they empty west into the Tennessee River.

For many years the Chattanooga area has been an important southern industrial center. Between 1950 and 1966, 350 new manufacturing plants were built in the area. These industries yield products such as explosives, paper, ceramics, chemicals, food, wood products, and metal products. With industry come more people, further development, and usually many sources of air pollution. Such has been the case in Chattanooga since the mid-1800's.

The first attempt to abate air pollution in Chattanooga was started in the mid-1920's. This was in the form of a boiler-inspection, smoke-control ordinance and expanded little until December 1951, when an improved, but still inadequate, ordinance was passed.

During recent years the local public has become keenly aware of the growing air pollution problem. Residents of Chattanooga, as well as those in the other cities and communities of the interstate metropolitan area, have become concerned with smoke, dust, odors, and reduced visibility. Complaints of soiling and particulate damage are normally the most numerous. These complaints are usually made in reference to emissions from industrial plants including a large number of metal processing plants and numerous soft-coal-burning operations. Because of local meteorological conditions and topography, and the frequency of thermal inversions, the situation is often aggravated and the pollutants become trapped in the valley.

In August 1963, Mayor Ralph Kelly requested that the U.S. Public Health Service provide the city with technical assistance in defining the nature and extent of the air pollution problem. In response to this request, the Division of Air Pollution conducted a 30-day survey during late November and early December 1963, in cooperation with the City of Chattanooga and the Tennessee Department of Public Health. Air quality measurements from this survey indicated that "smoke, dust, and other particulate material" were the primary air pollution problem in Chattanooga and that measurements significantly exceeded the national average for cities of similar size.

In 1965, the U.S. Army reactivated the Volunteer Army Ammunition Plant at nearby Tyner, Tennessee, to produce explosives needed for defense. Shortly thereafter numerous complaints of particulate and gaseous emissions were received by various governmental officials from many irate citizens in the surrounding area. For this reason, in 1967, the U.S. Army Environmental Health Agency, Edgewood Arsenal, published a summary of the air pollution problems associated with the operation of the Volunteer Army Ammunition Plant. The summary, which covered the period from December 1965 to February 1967, described the operation of the plant, identified points and magnitudes of major emissions, described the air quality measuring program, and discussed the abatement program under way. One report recommendation was that the U.S. Public Health Service assist with a comprehensive micro-meteorological study of the plant area to gather information pertinent to the dispersion and diffusion of pollutants. On March 24, 1967, a meeting was held between representatives of the Department of Defense and the U.S. Public Health Service, National Center for Air Pollution Control to discuss the recommendations of the 1967 report. As a result of this meeting NCAPC was formally requested to conduct a micro-meteorological survey at the ammunition plant.

Under provisions of the Air Quality Act of 1967 (Public Law 88-206), the Secretary of Health, Education, and Welfare is designated the responsibility for gathering air quality information in areas where interstate transportation of pollutants might reasonably be expected to occur. Because the Chattanooga area is interstate in nature, and because of considerable local concern about air pollution, on July 27, 1967, Mayor Ralph Kelly requested the Secretary to assist in conducting a comprehensive area-wide air quality survey.

On October 1, 1967, an air quality survey was begun in the Chattanooga, Tennessee - Rossville, Georgia, interstate area to fulfill both the request of the Department of Defense and the City of Chattanooga. The survey was coordinated by the Field Operations Branch, Division of Abatement, National Air Pollution Control Administration (NAPCA) in conjunction with:

1. Chattanooga Bureau of Air Pollution Control and Boiler Inspection.
2. Tennessee State Department of Public Health.

3. Georgia State Department of Public Health.
4. Hamilton County Health Department.
5. Walker County Health Department.
6. Catoosa County Health Department.
7. U.S. Army Hygiene Agency.

In addition to the previously mentioned air quality survey, four other investigations were conducted in the area during the period from October 1967 through April 1969:

1. Meteorological measurements.
2. Vegetation effects measurements.
3. Materials effects studies.
4. Emissions survey.

This report concerns these investigations and their results.

BLANK PAGE

2. METEOROLOGY

In air pollution control activities, two of the most important meteorological parameters are wind speed and direction. The dilution rate for pollutants emitted from a source varies in proportion to the wind speed. Wind direction indicates the path that pollutants take from their sources.

Atmospheric stability is also an important dilution factor. Stability is related to the vertical transfer of momentum, or more simply to atmospheric mixing. When the air temperature decreases with height at a rate greater than 5.4° F per thousand feet, the air is unstable and turbulence is enhanced. Conversely, when the temperature decreases at a lesser rate with height, the air is said to be stable and vertical motions are dampened or reduced.

The patterns of wind speed and direction, as well as stability, are influenced by topography, season, and time of day. To investigate these patterns, NAPCA, cooperating with the participating agencies, conducted a meteorological study in the interstate study area during 1967 and 1968. The following sections of this chapter contain a description of the climatology of the area, as well as the results and conclusions drawn from the meteorological study.

2.1 CLIMATOLOGY

The topography of the region contributes to average weather conditions that are particularly unfavorable for the dispersion of pollutants. The terrain tends to channel the airflow, reduce wind speeds, and enhance the frequency of occurrence of temperature inversions.

The wind roses* in Figure 2-1 show the annual wind pattern for Lovell Field from 1951 through 1960. The wind direction, which tended to be parallel to the valley orientation, indicates channeling. The average wind speed was only 6.1 miles per hour with calms occurring about a quarter of the time. Over the same 10-year period, the average wind speed at Los Angeles, a location known for very low wind speeds, was nearly the same.

A study of low-level inversions by Hosler,[1] based on historical upper air data across the nation, indicated that inversions below 500 feet occur at exposed locations in the Chattanooga vicinity about 30 to 50 percent of the time. The Southern Appalachian region was found to have the highest frequency of such inversions east of the Mississippi. In the United States, only parts of the western desert and mountain regions experienced higher inversion frequencies.

---

*A wind rose is a type of frequency distribution diagram used to show the relative frequency of observed wind speeds in terms of compass directions, for a given location. "Petal" lengths represent the percent of observations during which particular speeds (indicated by the legend) are observed from particular petal directions. Numbers indicate the percent of wind observations recorded in particular directions, with the center number indicating the percent of "calm" observations. Data are based on 1-hour averages over a selected time span.

Preceding page blank

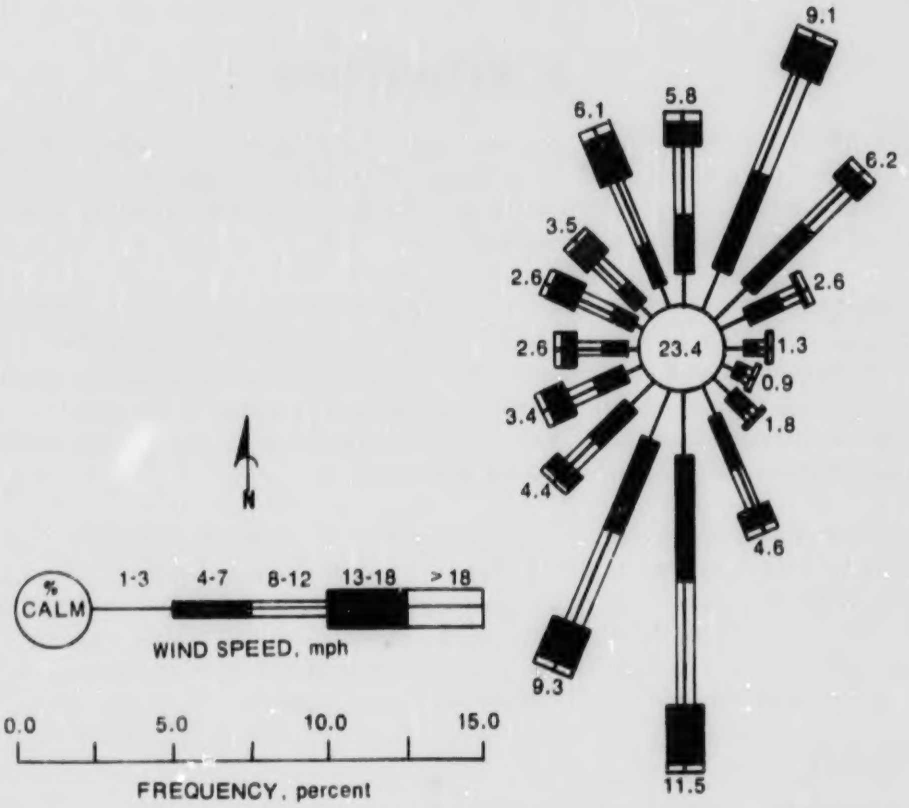


Figure 2-1. Lovell Field annual wind rose, 1951-60. Frequency distribution of wind speeds and direction by percent of total wind observations from direction of petals.

Seasonal variations in diffusion climate are significant. In winter, winds aloft are normally strong. Frontal passages occur in rather rapid succession and bring with them periods of favorable dispersion. Surface winds are the strongest and most variable during this season. Although spring is characterized by showery, often turbulent conditions, there is also an increase in clear skies conducive to more frequent nighttime inversions. Summer weather is markedly affected by the Bermuda high pressure system. The Bermuda high brings warm gentle breezes, few clouds, and increased frequency of nighttime stability. The fall season brings a gradual increase in frontal activity. The early fall, however, reflects summer conditions. Average autumn winds remain light, and stable nighttime conditions are frequent. Seasonal wind patterns are shown in Figure 2-2.

In general, the valley sectors of the study area experience less favorable dispersion conditions than the more exposed ridge-level locations. Pools of relatively cold stable air tend to collect in the valleys at night; hence, temperature inversions are likely to be more persistent there than on the ridges. Inversion formation is further enhanced by the sheltering ridges that block the general wind flow and cause localized stratification of the air in the lowest levels.

2.2 METEOROLOGICAL INVESTIGATIONS

Since 1940, the U.S. Weather Bureau has maintained a weather station at Lovell Field (site #14), which records wind speed and direction, temperature,

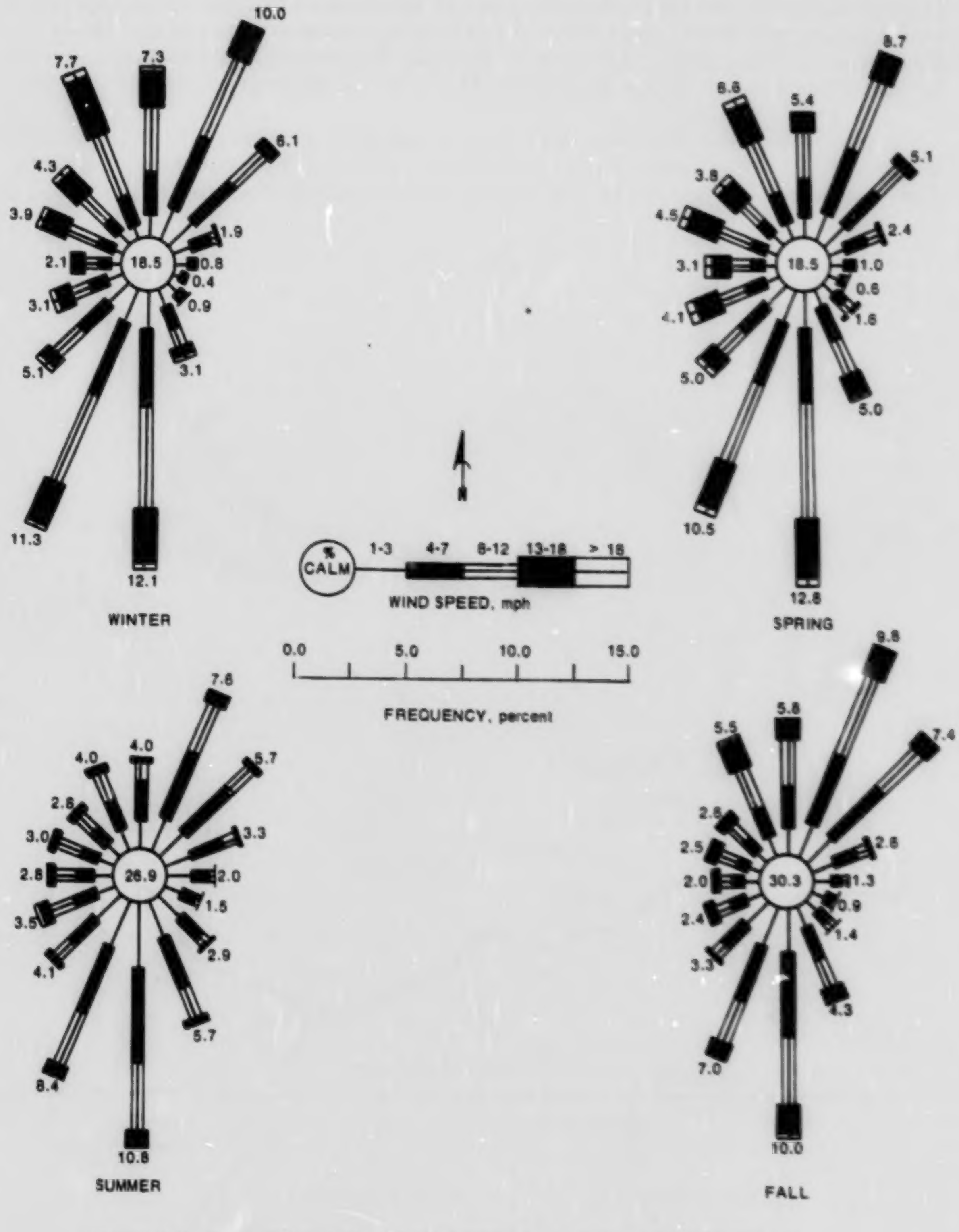


Figure 2-2. Seasonal variation of wind roses for Lovell Field, Chattanooga, Tennessee, 1951-1960.

pressure, cloud cover, and precipitation. This location can be considered a reliable indicator of wind conditions east of Missionary Ridge. Observations of temperature and cloud cover here are generally representative of the entire three-county study area. Additional sampling stations were established throughout the study area to obtain supplementary wind and atmospheric stability data.

Wind speed and direction data were obtained at sites #1, #7, #51, and #161 (Figure 2-3), for varying time periods from October 1967 until December 1968. These data were broken down into hourly values and summarized in the wind roses

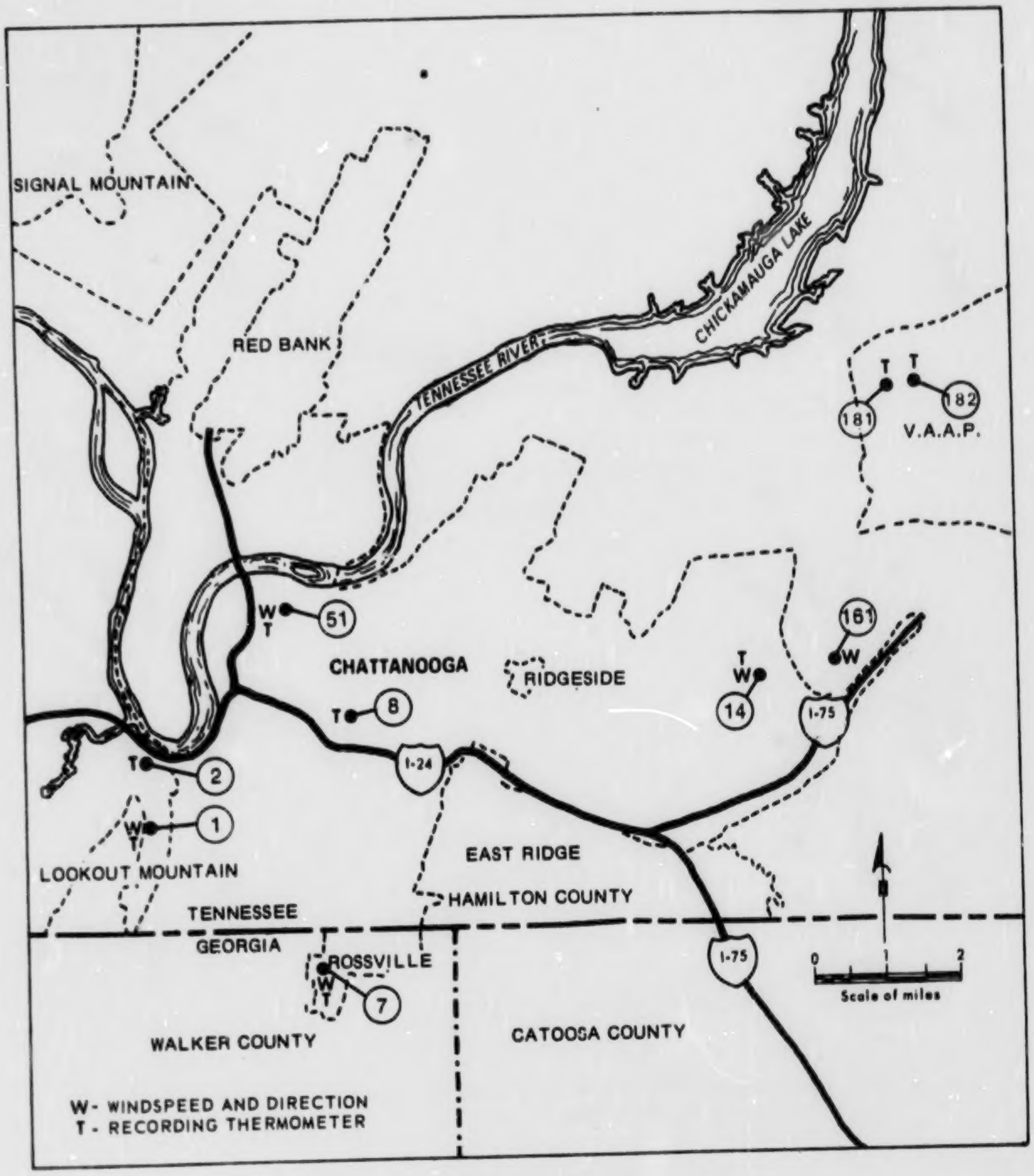

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
T
T
181
182
V.A.A.P.
W
T
51
CHATTANOOGA
RIDGESIDE
161
W
T
W
14
T
8
I-75
I-24
T
2
W
T
1
LOOKOUT MOUNTAIN
EAST RIDGE
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
W
T
7
I-75
0
1
2
Scale of miles
WALKER COUNTY
CATOOSA COUNTY
W- WINDSPEED AND DIRECTION
T - RECORDING THERMOMETER

Figure 2-3. Meteorological sampling sites.

presented in Appendix A and elsewhere in this report. Descriptions of each site are also contained in Appendix A.

Atmospheric stability is usually determined from vertical temperature measurements or inferred from surface observations. Two procedures were used to estimate stability during the study. First, thermographs were located at eight sites (see Figure 2-3). The sites were arranged in pairs of high- and low-terrain elevation. Hourly temperature measurements at the higher elevations were compared with corresponding lower elevation measurements to obtain a vertical temperature difference. Such temperature differences, although not strictly equated with lapse rate, do represent a continuous indicator of changing stability conditions in the valley.

Second, to substantiate atmospheric stability measurements taken by the thermographs, a NAPCA meteorological field team conducted both intensive upper wind observations (using single and double theodolite measurements) and temperature-lapse rate measurements (using a tethered balloon) on three separate occasions.

2.2.1 Wind Speed and Direction Measurements

Wind speed and direction measurements from Lovell Field for the 10-year period, 1951 to 1960, are given in Figures 2-1 and 2-2. The flow patterns shown by these wind roses are typical of other lee-of-the-mountain valleys in the southern Appalachians and indicate an up- or down-valley wind pattern closely corresponding to the orientation of Missionary and Boynton Ridges. The up-valley pattern encompasses a wider range of directions and is predominant over the down-valley pattern.

The 10-year seasonal wind roses from Lovell Field reveal several features. Spring and winter have higher wind speeds and a wider range of directions than the other seasons, although valley sheltering effects are still reflected by a frequency of calms that exceeds 18 percent. During summer and fall, the percentage of calms almost doubles and local patterns become more important as shown by the increase in southerly and northeasterly airflow.

There were few variations between the 10-year wind roses and the 1967 through 1968 survey-period wind roses for Lovell Field (see Appendix A). With the exception of slightly more southerly and fewer northeasterly winds, the survey period data can be said to reflect average wind flow conditions in the area.

The wind roses for the fall of 1967 and spring of 1968 have been selected for illustration. Data for these seasons are nearly complete and therefore readily comparable between stations. It appears, from the remaining data, that the comparisons are generally applicable to other seasons. These two seasons characterize average dispersion conditions that are relatively favorable in spring and poor in the fall.

Measurements were taken at Hickory Valley (site #161) and Lovell Field (site #14) in the area east of Missionary Ridge. The spring results, shown in Figure 2-4, indicate that the Hickory Valley drainage (or down-valley direction) is between north and northeast while Lovell Field's drainage is north. Except for this directional difference and the difference in percentage of calms, 5.3 percent and 19.3 percent, the results from these two sites are very similar. The higher

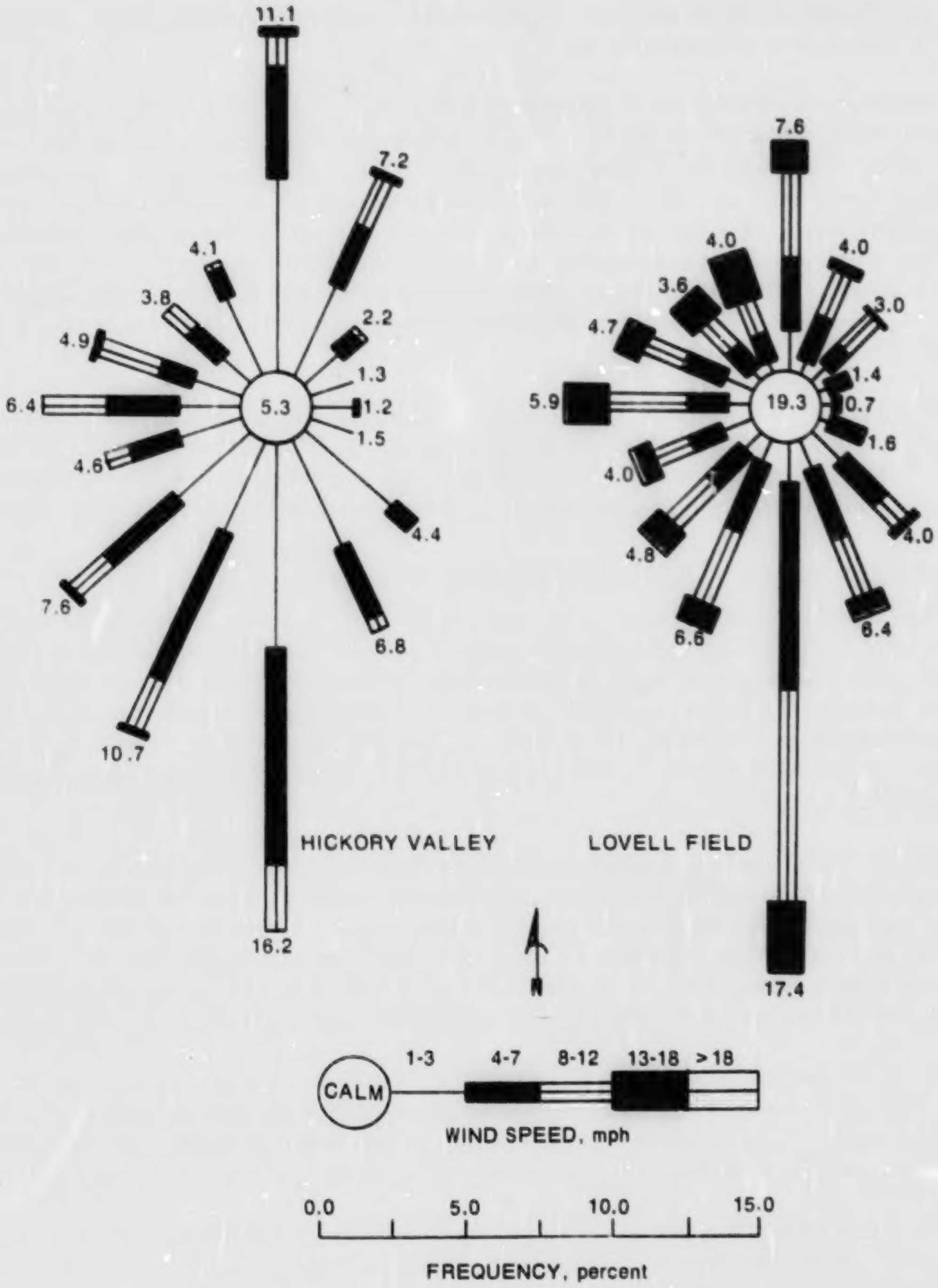


Figure 2-4. Wind roses for area east of Missionary Ridge, Spring 1968.

starting speed of the wind instrument at Lovell Field was possibly responsible for the difference in calms.

Two wind sites, Volunteer Life (site #51) and Rossville, Georgia (site #7), were located west of Missionary Ridge in the Chattanooga valley. The wind roses (Figure 2-5) for fall and spring are similar for the Rossville site with the predominant winds from the southwestern quadrant and from the north, reflecting the

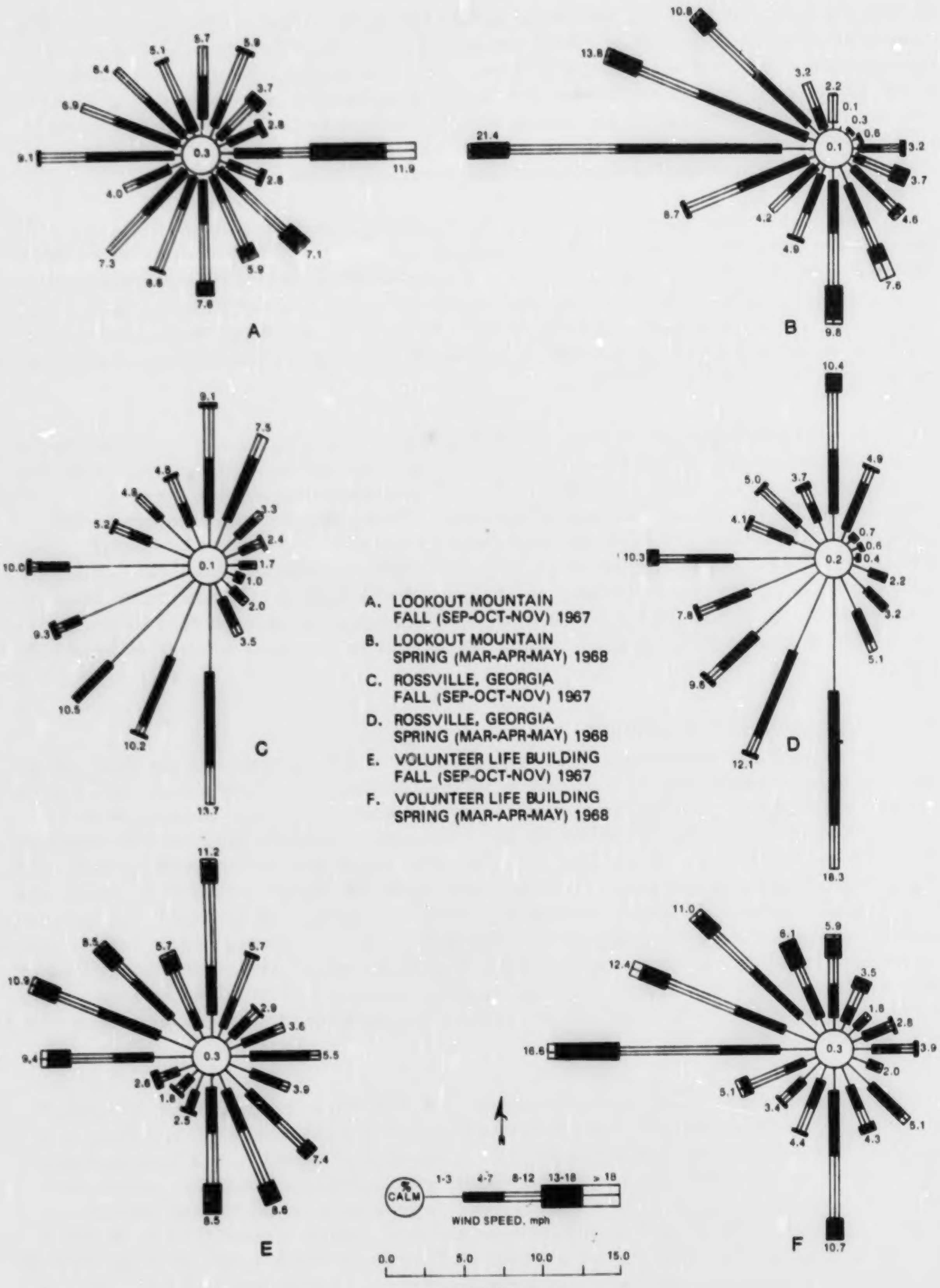


Figure 2-5. Influence of topography on spring (1968) and fall (1967) wind roses from meteorological sampling sites west of Missionary Ridge.

strong influence of Lookout Mountain and Missionary Ridge. Volunteer Life, the downtown Chattanooga station, does not experience the blocking effect from Lookout Mountain that the Rossville site does. The Volunteer Life site was situated close to the gap, between Lookout and Signal Mountains. Because of this location and the seasonal changes in the upper winds, Volunteer Life had a Fall 1967 wind pattern predominantly from the northwest and southeast quadrants, and a Spring 1968 pattern from the west-northwest and from the south.

Fall and spring wind roses from the Lookout Mountain site (see Figure 2-5) provide the best indication of the flow patterns above the Chattanooga valley floor. These roses, however, may not be fully representative of the free atmospheric flow above the valley since the airflow at the site was subject to some modification by the flow about the mountain itself. In the fall, stronger west-east winds were present and in the spring west-northwest flow was predominate, accompanied by limited flow from the south.

Topography appears to be a governing factor for wind speed and direction in both patterns shown and in those from the four other sites. Topographic features create two separate flow systems in the Chattanooga area, one east of Missionary Ridge and one west of the ridge. These systems often operate independently, resulting in a limited interchange of pollutants across the ridge. The small percentage of northeasterly winds recorded at Lookout Mountain and the flow patterns for Hickory Valley and Lovell Field indicate that pollutants from the Volunteer Army Ammunition Plant area are infrequently transported to the downtown Chattanooga area, tending instead to remain in the area west of Missionary Ridge.

2.2.2 Inversion Measurements

Thermograph measurements were made in order to estimate the frequency and strength of temperature inversions in the Chattanooga study area. In a ridge-valley relationship, the daytime surface temperatures at ridge-level tend to be cooler than at the valley floor but warmer than the corresponding free air temperature above the valley. The difference between ridge and floor thermograph readings would then be less than the actual lapse rate, showing more stable conditions than actually exist. At night, conditions reverse, and readings would indicate less stable conditions than actually exist. Therefore, the percentage of nighttime inversions measured by the thermographic method is a conservative estimate. Under this restriction, temperature inversions were recorded in the Chattanooga valley west of Missionary Ridge over 60 percent of the nighttime hours during the summer and 35 percent during the winter.

To illustrate the inversion conditions west of Missionary Ridge, Table 2-1 was developed from temperature differences between thermograph readings recorded at Ruby Falls and at Rossville. Two typical months, one summer and one fall, were selected for comparison and only nighttime conditions were considered. Positive temperature differences represent a trend toward stable or inversion conditions; negative differences point to unstable conditions. Information presented in the table shows a rapid shift toward stable conditions (increased percentage of positive values) after sunset during both summer and fall. A sizeable increase in the percentage of positive values occurs in the summer (June) as compared to the fall (November). Though fewer inversions occur in the fall, the

Table 2-1. NIGHTTIME TEMPERATURE DIFFERENCES: RUBY FALLS MINUS ROSSVILLE, JUNE 1968 AND NOVEMBER 1967

Time of day (EST)	Temperature difference, °F									Cumulative inversions,[a] %
	< -6	-5.9 to -3.0	-2.9 to 0.0	0.1 to 3.0	3.1 to 6.0	6.1 to 9.0	9.1 to 12.0	12.1 to 15.0	>15.0	
Occurrence June 1968,[b] %										
19	18	51	23	8	-	-	-	-	-	8
20	-	23	37	25	15	-	-	-	-	40
21	-	19	15	41	17	8	-	-	-	66
22	-	9	25	23	22	18	3	-	-	66
23	-	12	7	26	27	25	3	-	-	81
00	4	8	7	11	30	37	3	-	-	81
01	3	9	6	12	36	31	3	-	-	82
02	7	6	4	13	38	29	3	-	-	83
03	6	7	9	8	43	13	11	3	-	78
04	3	10	4	10	35	25	9	4	-	83
05	3	6	8	20	30	23	6	4	-	83
Occurrence November 1967,[c] %										
18	-	27	43	20	7	3	-	-	-	30
19	-	24	39	10	14	8	5	-	-	37
20	1	26	30	10	13	11	6	3	-	43
21	2	27	28	13	10	6	4	6	4	43
22	-	23	27	17	9	4	12	7	1	50
23	-	20	30	13	11	6	10	6	4	50
00	-	19	34	7	12	11	9	4	4	47
01	-	22	33	10	12	3	12	7	1	45
02	-	22	28	8	15	13	6	8	-	50
03	-	13	34	6	23	10	6	8	-	53
04	-	13	30	16	17	10	10	4	-	57
05	-	10	27	13	17	18	11	4	-	63
06	-	13	29	16	12	14	13	3	-	58

[a] Defined as positive temperature differences.
[b] Average sunset 1940, average sunrise 0535.
[c] Average sunset 1730, average sunrise 0750.

magnitude or strength of the fall inversions is greater. Fall temperature differences between the two altitudes were as great as 15° F.

To further illustrate the distribution of temperature differences within the study area, average hourly differences are plotted in Figure 2-6 for pairs of stations, one pair east and one west of Missionary Ridge. The month of March 1968 was arbitrarily selected for the comparisons. West of Missionary Ridge, between Lookout Mountain and Rossville, and also between Ruby Falls and Rossville, inversion trends (positive temperature differences) persisted in the Chattanooga valley from 2100 until 0800. A rapid decrease in stability occurred from 0700 until 1100. More unstable conditions existed until about 1700, whereupon, a rapid trend toward stability began, approximately coinciding with sunset.

In Figure 2-6 a slightly different stability pattern for the area east of Missionary Ridge is shown by the Farmer's Chemical site. Nighttime conditions are similar to those west of the ridge, but daytime conditions reflect a smaller decrease in stability. The average temperature difference is nearly isothermal until about 1400. At that time, afternoon heating causes an increased instability until about 1800, when a rapid trend toward stability begins again. The patterns in the two valleys show some differences; however, a large part of these differences may be due to the variation in the height between the paired stations.

2.3 SUMMARY AND CONCLUSIONS

The climatology of the study area indicates light average wind speeds, topographically confined flow, and frequent inversion conditions. These are factors

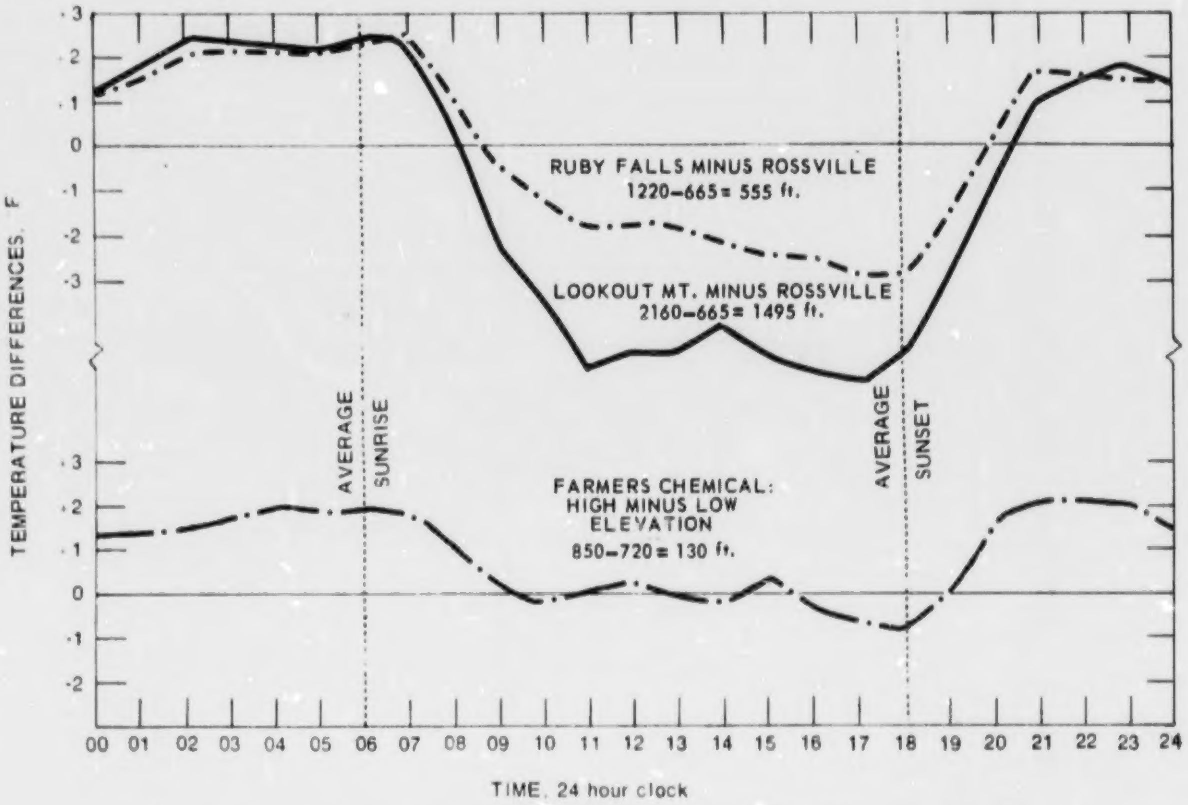


Figure 2-6. Comparison of average March, 1968 temperature differences between selected sites.

usually associated with poor pollutant dispersion. In addition, the frequency of prolonged periods of particularly poor dispersion conditions is greater than in most other parts of the nation. Figure 2-7 shows that the Chattanooga area lies near the geographical region having the maximum "high-air-pollution-potential forecast days"* for the eastern United States.

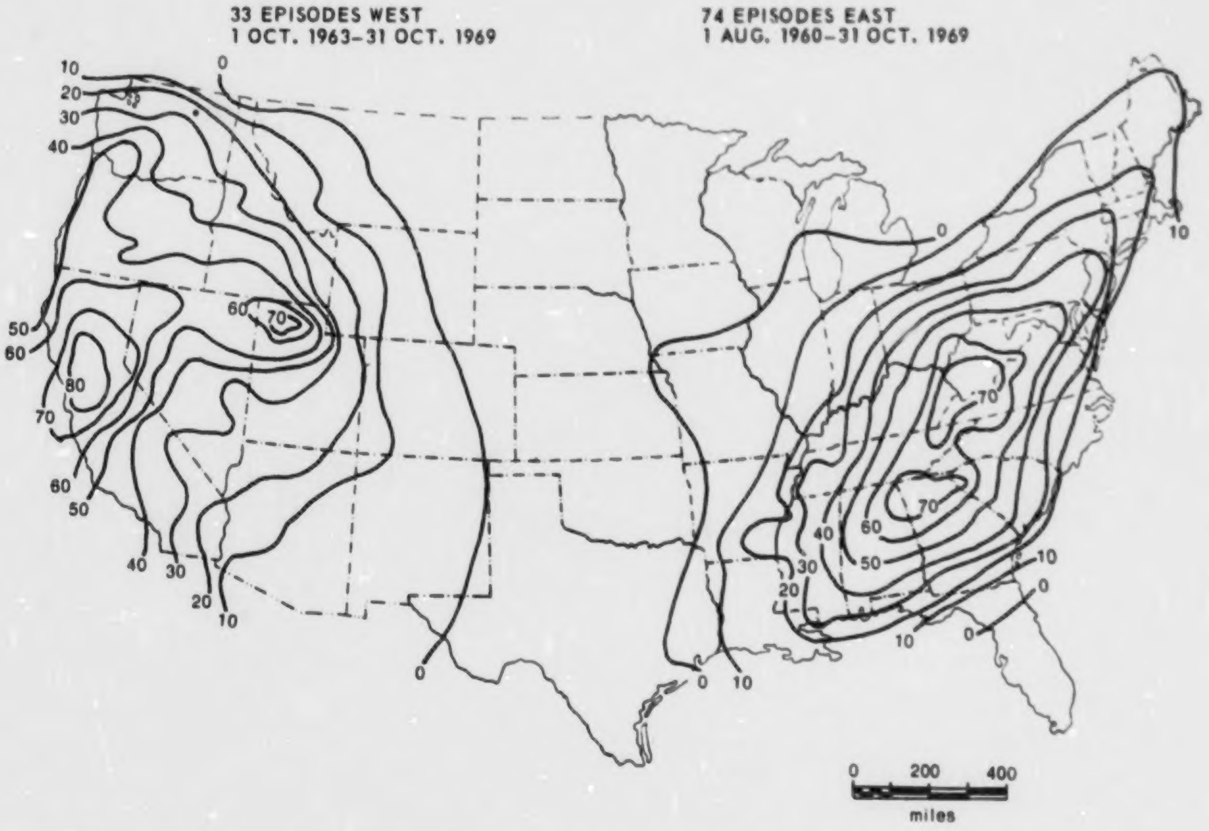


Figure 2-7. Forecast high-air-pollution-potential days.

On a local scale, the meteorological picture emerging from studies contained in this chapter is of two valleys that typify conditions along the eastern slopes of the Appalachians. Valley flow is sluggish with many calm periods. The airflow pattern is essentially up- or down- with very little cross-valley circulation. East of Missionary Ridge the area is primarily rural with scattered homes and only one major source of air pollution—the Volunteer Army Ammunition Plant. The pollutants emitted in the area are usually confined by nighttime inversions and transported up or down the valley until the inversions break up.

The other valley, west of Missionary Ridge, tends to have stronger winds and more frequent cross-valley flow. The area is primarily urban with many industrial sources of pollution, which contribute to a more even distribution of pollutants throughout that valley. No evidence was found to indicate any major transport of pollutants from one valley to the other. In fact, wind roses from the separate valleys indicate that very little pollutant exchange occurs.

---

*These forecasts have been issued by the U.S. Weather Bureau since 1960 for regional episodes expected to persist for at least 36 hours.

BLANK PAGE

3. AIR QUALITY MEASUREMENTS

A 29-station air sampling network was set up to examine the air quality of the interstate area. Whenever possible, sampling locations were selected to satisfy the following objectives:

1. To determine the spatial distribution of pollutants throughout the area, describing areas of maximum pollution and developing a gradation of pollutant concentrations.
2. To determine the air quality levels in each of the four major zone classifications - residential, commercial, industrial, and rural.

Care was exercised to ensure that all sampling stations were representative of the area in which they were located. Figure 3-1 indicates the location of each sampling station. A description of each and its instrumentation is given in Appendix B.

Pollutants sampled were: particulates, sulfur dioxide, nitrogen oxides, oxidants, carbon monoxide, and hydrocarbons. Selected suspended particulate samples were also analyzed for sulfate, ammonium, and nitrate content.

3.1 PARTICULATE POLLUTANTS

Particulate air pollution is any matter dispersed in the air "in which the individual particles are larger than small molecules, but smaller than 500 microns (μ) in diameter."[2] This type of pollution is generally classified into two main categories, either suspended or settleable particulate. Particles greater than 10 μ in diameter tend to settle rapidly from the air and are classified as settleable; while particles smaller than this diameter tend to remain in suspension for longer periods of time, thus being classified as suspended.

3.1.1 Suspended Particulate—High-Volume Samplers

Suspended particulate is most commonly measured with high-volume samplers. Twenty-one sampling stations were established in the study area, and samples were collected for 24-hour periods beginning at midnight. Results, reported in micrograms per cubic meter ($\mu g/m^3$), are summarized by frequency distribution in Table 3-1. Graphic illustrations of these distributions also appear in Appendix C and a comparison of mean values, in Figure 3-2. High average concentrations were recorded at the National Guard (site #8), and at the Volunteer Army Ammunition Plant (VAAP) (sites #17 and #19). These three sites along with Rossville (site #7), WDEF-TV (site #4), and the Rod and Gun Club (site #20), all recorded daily values in excess of 400 $\mu g/m^3$. Table 3-2 shows the percent of time selected concentration levels were exceeded. Levels in excess of 150 $\mu g/m^3$ were found at least 20 percent of the time at nine of the stations.

Preceding page blank

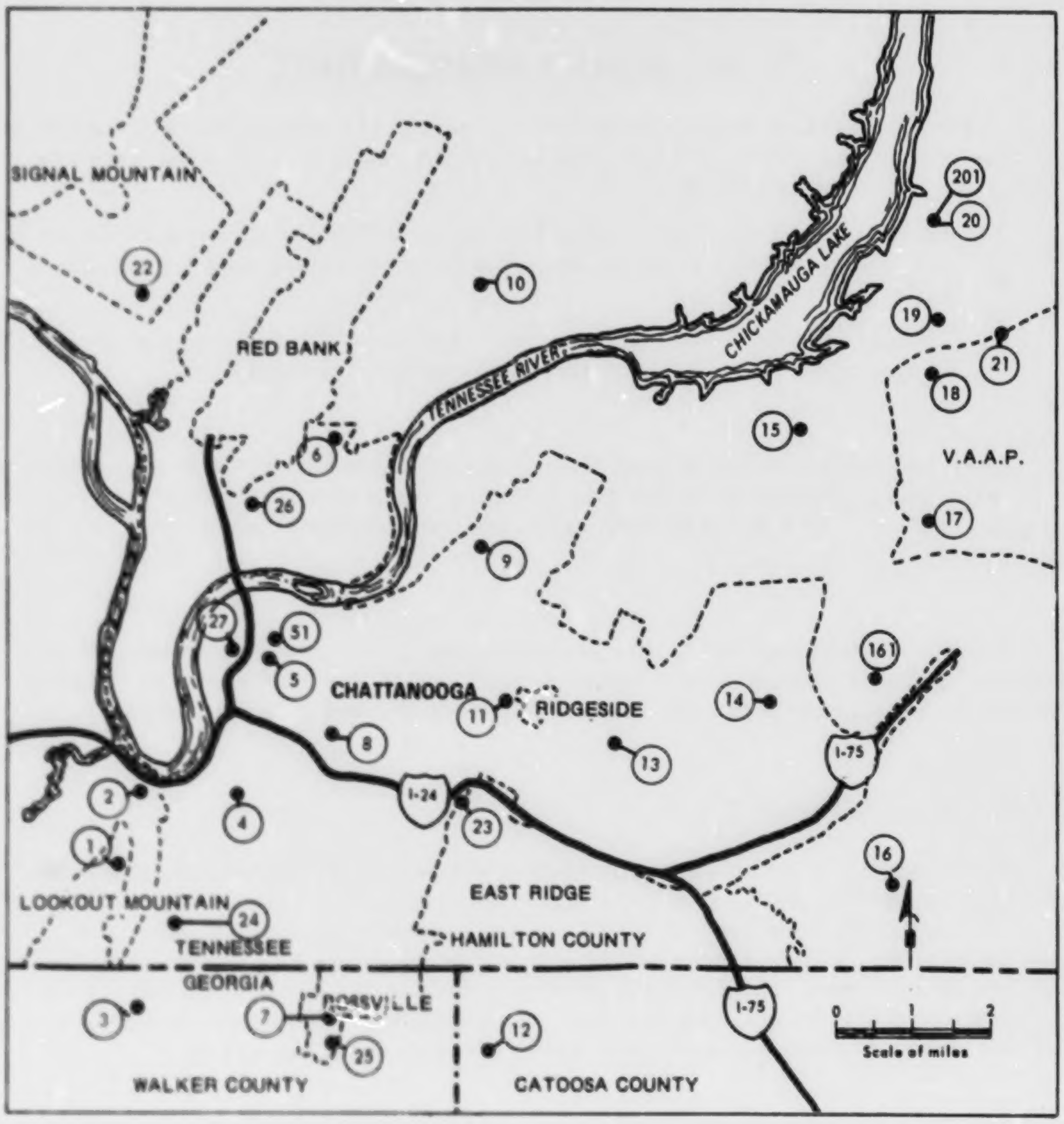

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
CHATTANOOGA
RIDGESIDE
LOOKOUT MOUNTAIN
EAST RIDGE
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
WALKER COUNTY
CATOOSA COUNTY
I-24
I-75
I-75
1
2
3
4
5
51
6
7
8
9
10
11
12
13
14
15
16
161
17
18
19
20
201
21
22
23
24
25
26
27
0
1
2
Scale of miles

Figure 3-1. Air quality sampling network stations (see Appendix B).

An isointensity map depicting the geographic distribution of suspended particulate concentrations throughout the study area is presented in Figure 3-3. This map shows two separate areas of high concentration, one centered in the valley including downtown Chattanooga extending south to include Rossville; and the other, a more narrow area, extending from the Rod and Gun Club south to beyond the VAAP administration area. The topographical features of the study area, which are described in detail elsewhere in this report, seem to rule out the possibility of any significant exchange of pollutant concentrations between these two areas. This apparent existence of separate air masses within the study area is strongly substantiated by the measured pollutant concentrations, not only the suspended particulate as shown in Table 3-1, but also by the measured levels of nitrogen dioxide that are discussed later.

Table 3-1. CUMULATIVE FREQUENCY DISTRIBUTION OF DAILY SUSPENDED PARTICULATE CONCENTRATION

Station number	Operating period	Number observations	Concentration, $\mu g/m^3$											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
1	10/67 - 12/68	146	20	30	45	62	78	105	105	10	48	22	43	1.7
3	10/67 - 11/68	186	26	40	62	89	118	172	185	12	66	34	57	1.8
4	10/67 - 12/68	193	46	64	94	138	195	350	478	21	108	61	94	1.8
5	10/67 - 11/68	179	60	74	99	139	191	338	358	35	116	64	103	1.6
6	10/67 - 12/68	153	32	45	66	94	132	237	286	17	76	42	66	1.7
7	10/67 - 12/68	227	44	64	96	141	203	376	511	18	114	73	96	1.8
8	10/67 - 12/68	215	55	89	140	207	290	521	697	33	160	102	134	1.9
9	10/67 - 12/68	179	49	69	100	145	202	359	383	28	114	64	100	1.7
10	10/67 - 3/68	69	21	37	63	98	135	-	178	17	72	40	62	2.1
11	10/67 - 12/68	149	27	37	53	76	104	180	198	14	60	34	53	1.7
12	10/67 - 12/68	194	29	41	59	87	124	273	323	10	68	42	59	1.8
13	10/67 - 12/68	162	28	38	55	78	109	188	214	14	64	35	57	1.7
14	10/67 - 12/68	183	27	43	66	96	130	221	302	14	76	44	64	1.8
15	12/67 - 12/68	125	23	36	56	82	115	208	209	14	64	36	54	1.9
16	10/67 - 3/68	59	20	32	51	75	101	-	168	15	56	33	48	1.9
17	9/67 - 11/68	425	43	73	120	183	255	396	414	20	135	78	113	2.0
19	9/67 - 11/68	422	30	63	116	190	262	364	586	12	133	89	103	2.3
20	9/67 - 11/68	408	20	45	89	153	223	340	432	13	108	77	83	2.6
21	9/67 - 11/68	424	32	47	70	108	155	299	345	10	84	52	70	1.8
27	4/68 - 12/68	69	64	84	112	150	194	-	308	39	118	50	109	1.5
201	6/68 - 11/68	55	21	37	62	94	127	-	257	7	72	52	56	2.0

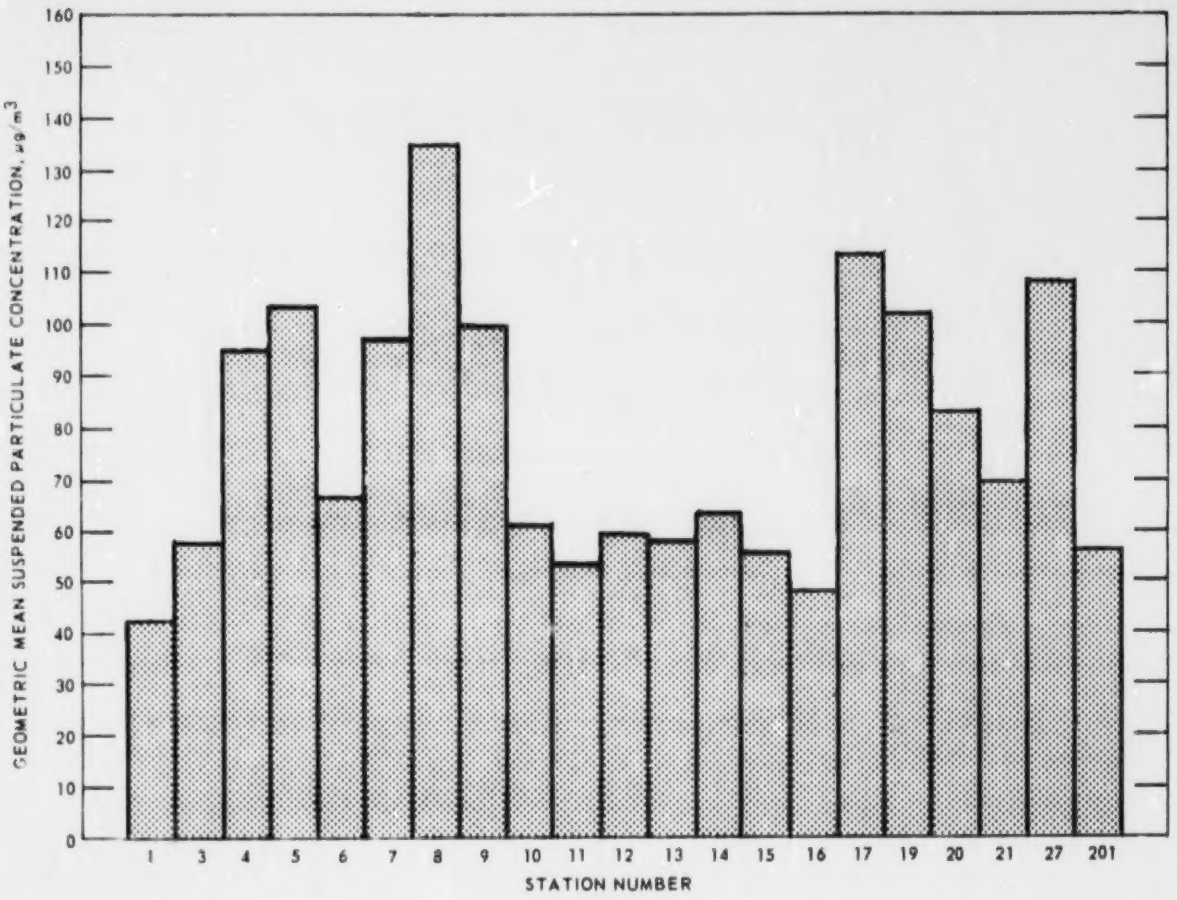


Figure 3-2. Comparison of annual geometric mean suspended particulate concentrations (μg/m^3) for all sampling stations, October 1967 - November 1968.

Air Quality Criteria for Particulate Matter[2] indicates that "in areas where studies have been conducted, adverse health effects were noted when the annual geometric mean level of particulate matter exceeded 80 μg/m^3, visibility reduction to about 5 miles was observed at 150 μg/m^3, and adverse effects on materials were observed when the annual geometric mean exceeded 60 μg/m^3." The values presented in Tables 3-1 and 3-2, and Figure 3-3 indicate that suspended particulate levels in many locations in the metropolitan Chattanooga area are, therefore, sufficiently high to warrant considerable concern by local residents.

3.1.2 Suspended Particulate — Respirable Dust Fraction

Suspended particulate material in the atmosphere is never uniform in size. The composition of the material, the source and manner of generation, the time elapsed since generation, and meteorological conditions are among the many factors that influence the size distribution of particles in the atmosphere.

Respiration carries airborne particles into the human body. Larger particles, in general, are deposited in the upper respiratory system, while particles between 1 and 5 μ in diameter tend to penetrate deeply and become deposited in the fine structure of the lungs.[3] Particles of this size and nature are identified as respirable.

Table 3-2. PERCENT OF OBSERVATIONS EXCEEDING SELECTED DAILY SUSPENDED PARTICULATE CONCENTRATIONS

Station number	Concentrations, μg/m^3				
	60	80	100	125	150
	% exceeding				
1	27	9	2	0	0
3	52	32	18	8	3
4	79	61	46	31	20
5	90	68	49	32	20
6	56	35	22	12	7
7	78	61	46	32	22
8	88	79	70	57	46
9	83	66	50	35	23
10	53	36	24	13	<1
11	40	22	11	5	2
12	49	30	18	10	6
13	43	24	13	6	3
14	57	38	22	12	6
15	45	26	15	8	4
16	39	21	10	<1	<1
17	82	71	60	48	37
19	76	66	57	47	37
20	66	55	45	34	26
21	60	42	29	18	11
27	92	78	60	40	24
201	52	35	22	11	<1

High-volume samplers generally collect some larger particles, which, though small in number, may exert a large influence upon the overall gravimetric result. The percentage or amount of the sample smaller than 5 μ in diameter is extremely important when the different aspects of particulate air pollution previously mentioned are considered. For this reason, five high-volume sampling stations were equipped with additional samplers that had cyclone prefilters designed to simulate the particle-size collection characteristics of the upper respiratory system.

Results of the respirable dust measurements are presented by seasonal averages in Table 3-3. The highest percentage of respirable dust was measured at the Rod and Gun Club (site #201); Rossville (site #7) samples contained the lowest percentage. In most recorded instances, as much as 40 percent of the particulate suspended in the air could be classified as respirable.

3.1.3 Suspended Particulate — Soiling Index

Soiling of draperies, clothing, and other domestic items is a nuisance that can be directly related to suspended particulate air pollution. Suspended particulate matter ranging from 2.0 μ to less than 0.3 μ plays an active role in the soiling of buildings and textiles.[1] In the early 1950's the tape sampler method[4] was devised in an attempt to document soiling effects.

The soiling potential, or "soiling index" of the atmosphere, was measured at six locations in the interstate area with paper tape samplers. Results, reported as coefficient of haze (Coh's) per 10^3 lineal feet, are presented as frequency distributions in Table 3-4 and Appendix C.

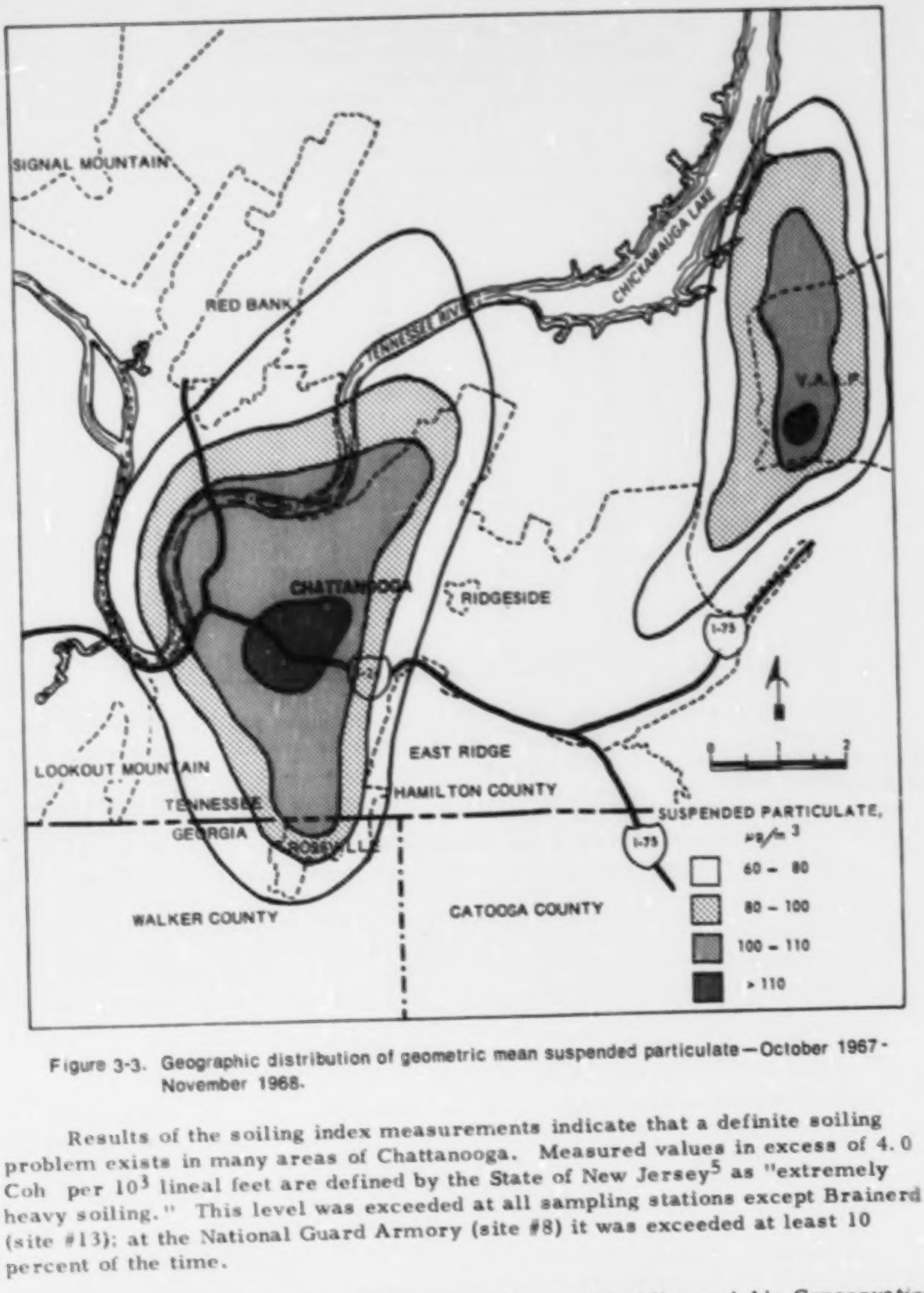

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
CHATTANOOGA
RIDGESIDE
I-75
EAST RIDGE
LOOKOUT MOUNTAIN
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
WALKER COUNTY
CATOOSA COUNTY
0 1 2
SUSPENDED PARTICULATE, µg/m 3
60 - 80
80 - 100
100 - 110
> 110

Figure 3-3. Geographic distribution of geometric mean suspended particulate—October 1967 - November 1968.

Results of the soiling index measurements indicate that a definite soiling problem exists in many areas of Chattanooga. Measured values in excess of 4.0 Coh per 10^3 lineal feet are defined by the State of New Jersey[5] as "extremely heavy soiling." This level was exceeded at all sampling stations except Brainerd (site #13); at the National Guard Armory (site #8) it was exceeded at least 10 percent of the time.

Other soiling index standards such as those of the Missouri Air Conservation Commission (0.4 Coh per 10^3 lineal feet, annual geometric mean)[6] or the State of

Table 3-3. CONCENTRATIONS OF SUSPENDED PARTICULATE ESTIMATED AS RESPIRABLE
(seasonal averages)

Station number	Date	Number observations	Suspended particulate, $\mu g/m^3$		Percent respirable
			Total	Respirable	
4	10/67 - 11/67	12	128	59	46
	12/67 - 2/68	23	118	56	47
	3/68 - 5/68	20	93	38	41
	6/68 - 8/68	22	99	40	40
	9/68 - 11/68	23	112	54	48
Arithmetic mean	10/67 - 11/68	100	108	49	45
5	12/67 - 2/68	3	166	43	26
	3/68 - 5/68	10	113	43	38
	6/68 - 8/68	19	92	43	47
	9/68 - 11/68	15	103	46	45
Arithmetic mean	12/67 - 11/68	47	104	44	42
7	4/68 - 5/68	9	91	32	35
	6/68 - 8/68	22	97	38	39
	9/68 - 11/68	27	145	48	33
Arithmetic mean	4/68 - 11/68	58	118	42	36
14	10/67 - 11/67	14	76	25	33
	3/68	6	64	37	58
Arithmetic mean	10/67 - 3/68	20	73	29	40
201	6/68 - 8/68	21	78	63	81
	9/68 - 11/68	26	72	51	71
Arithmetic mean	6/68 - 11/68	47	75	56	75

Tennessee industrial area limitation (5.0 Coh per 10^3 lineal feet not to be exceeded 1 percent of the time during any 30-day period)[7] are based on longer term averages. Information presented in Table 3-4 indicates that these standards were equaled or exceeded at the majority of locations in the study area.

3.1.4 Settleable Particulate—Dustfall

Dustfall measurements, using jars or other containers, have been taken as indicators of settleable particulate pollution since the early 1900's.[8] Values are expressed as tons/mi^2-mo (or g/cm^2-mo), and roughly represent an area with an approximate radius of 0.25 mile. Most of the particles collected are in the range of 20 to 40 μ in diameter.[2] This measurement does not, therefore, consider the smaller particles, which are a major cause of soiling, visibility reduction, and respiratory problems. Instead, dustfall measurements provide a general index of pollution from sources of larger particulate matter.

Measurements were taken at 28 stations in the study area. Results are summarized in Table 3-5. The highest mean dustfall values were recorded at VAAP-Pond (site #19) and at the effects station in Rossville (site #141), which had values of 30 and 20 tons/mi^2-mo, respectively.

The geographic pattern of the dustfall measurements shown in Figure 3-4 is very similar to that of suspended particulate. As with suspended particulate,

Table 3-4. CUMULATIVE FREQUENCY DISTRIBUTION OF 2-HOUR SOILING INDEX MEASUREMENTS

Station number	Operating period	Number observations	Soiling index, Coh/10^3 lineal ft											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
4	7/68 - 11/68	1,202	0.3	0.5	0.9	1.5	2.7	4.6	5.7	0.1	1.2	1.0	0.8	2.5
5	10/67 - 11/68	3,595	0.2	0.3	0.8	1.7	3.0	6.5	9.5	0.1	1.3	1.4	0.8	3.0
7	9/67 - 11/68	4,514	0.1	0.2	0.5	1.3	2.7	5.4	8.7	0.1	1.0	1.2	0.5	3.3
8	10/67 - 11/68	3,336	0.2	0.4	0.9	2.2	4.3	8.0	10.0	0.1	1.6	1.8	0.9	3.1
9	10/67 - 11/68	4,497	0.1	0.3	0.5	1.1	2.4	5.6	10.0	0.1	0.9	1.1	0.5	2.9
13	9/67 - 11/68	693	0.3	0.4	0.6	1.0	1.5	2.8	3.7	0.1	0.8	0.6	0.6	2.1

Table 3-5. SETTLEABLE PARTICULATE (DUSTFALL) MEASUREMENTS
($tons/mi^2 - mo$)

Station number	Operating period	Number observations	Minimum value	Maximum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
1	10/67 - 11/68	13	4	15	7	3	7	1.5
2	10/67 - 11/68	12	6	15	9	3	9	1.3
3	10/67 - 11/68	14	1	11	7	3	6	2.0
4	10/67 - 11/68	14	5	27	18	6	16	1.6
6	10/67 - 11/68	13	3	11	8	2	7	1.4
7	10/67 - 11/68	14	5	18	12	4	11	1.4
8	10/67 - 11/68	13	8	16	12	2	12	1.2
9	10/67 - 11/68	14	3	15	8	3	8	1.6
10	10/67 - 11/68	12	4	9	6	2	6	1.3
11	10/67 - 11/68	10	6	24	11	5	10	1.5
12	10/67 - 11/68	12	5	14	8	2	7	1.3
13	10/67 - 11/68	14	2	12	7	3	6	1.7
14	10/67 - 11/68	14	3	13	8	2	7	1.4
15	10/67 - 11/68	14	1	33	12	9	8	2.5
16	10/67 - 3/68	5	2	5	3	1	3	1.4
18	10/67 - 11/68	11	4	28	11	7	10	1.7
22	10/67 - 11/68	12	5	17	10	3	10	1.4
23	10/67 - 3/68	5	5	40	14	15	10	2.3
24	10/67 - 11/68	11	4	15	10	3	9	1.5
25	11/67 - 11/68	10	7	27	16	7	14	1.6
26	12/67 - 3/68	4	4	17	9	6	8	1.8
27	5/68 - 11/68	6	6	36	14	11	11	1.8
107E (19)	10/67 - 11/68	12	15	51	30	12	28	1.5
108E (17)	10/67 - 11/68	14	8	16	12	2	11	1.2
109E (21)	10/67 - 11/68	13	3	29	11	7	9	1.8
110E (20)	10/67 - 11/68	14	6	32	13	7	12	1.6
140E (5)	10/67 - 11/68	14	12	32	17	5	17	1.3
141E	10/67 - 11/68	14	9	32	20	6	19	1.4

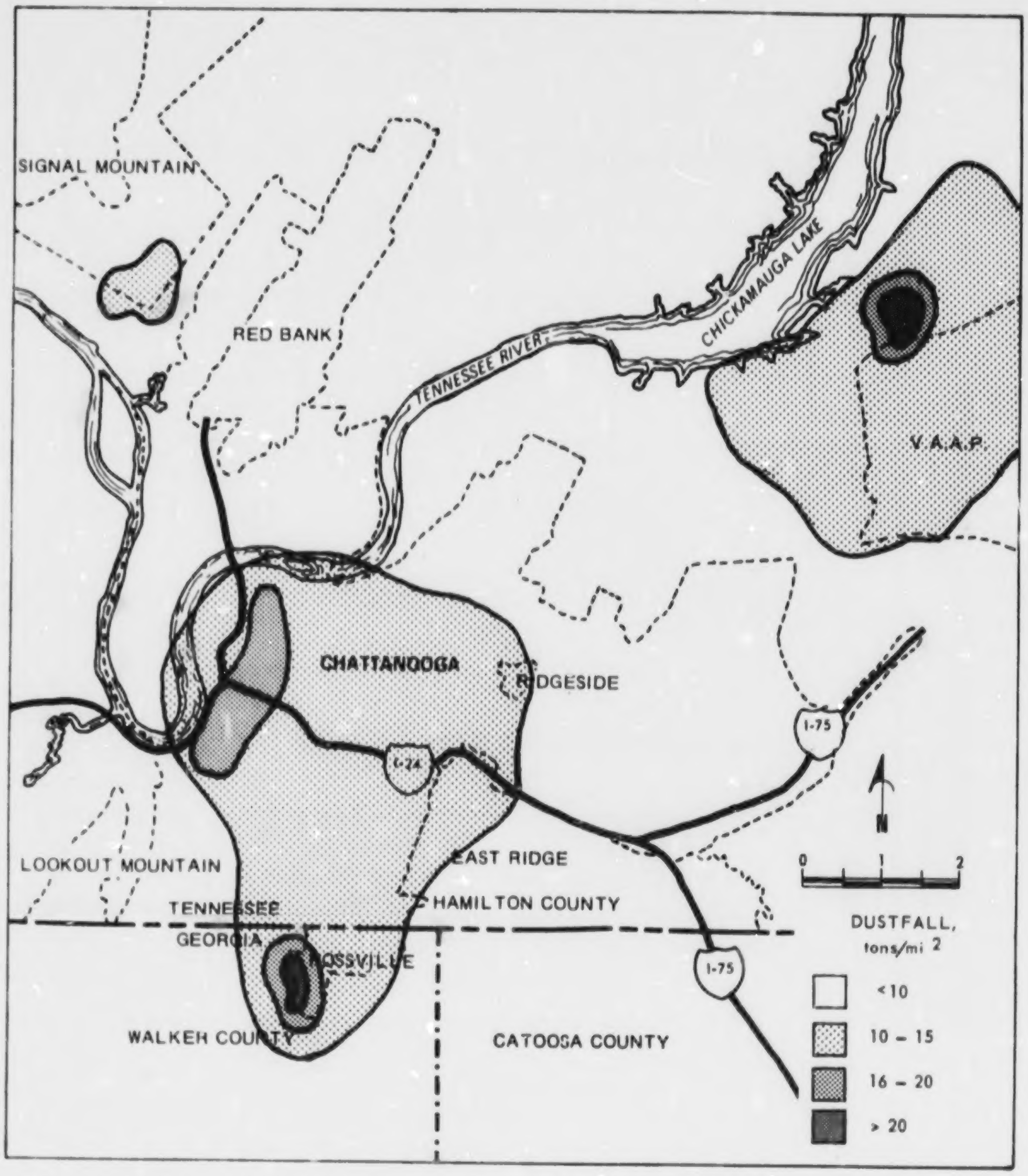

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
CHATTANOOGA
RIDGESIDE
I-75
I-24
N
0 1 2
LOOKOUT MOUNTAIN
EAST RIDGE
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
I-75
WALKER COUNTY
CATOOSA COUNTY
DUSTFALL, tons/mi 2
<10
10 – 15
16 – 20
> 20

Figure 3-4. Geographic distribution of arithmetic mean settleable particulate - October 1967 - November 1968.

there are two areas of high concentration with no apparent exchange of pollutant between them. Highest geographical concentrations were found at Rossville, in downtown Chattanooga, and at the VAAP-Pond.

3.2 SULFUR DIOXIDE

Sulfur dioxide (SO_2) is a gaseous pollutant principally derived from the combustion of coal and other sulfur-bearing fossil fuels. It is suspected as one of the chief culprits in numerous past air pollution episodes and is responsible for effects such as visibility reduction, metal corrosion, material and vegetation damage, and damage to the human respiratory system. Such effects are rapidly accelerated in the presence of suspended particulate material.[9]

Area-wide SO_2 pollution was examined by a sampling network composed of **10 stations (see Figure 3-5).** Three **sampling** methods[10] **were used:** (1) West-Gaeke sequential, (2) West-Gaeke automatic continuous, and (3) electroconductivity automatic continuous. In addition, lead dioxide candles, which provide a rough indication of the sulfation rate of an area,[7] were employed at 27 stations. Table B-1 of Appendix B contains a listing of all SO_2 stations, sampling times, and methods of analysis.

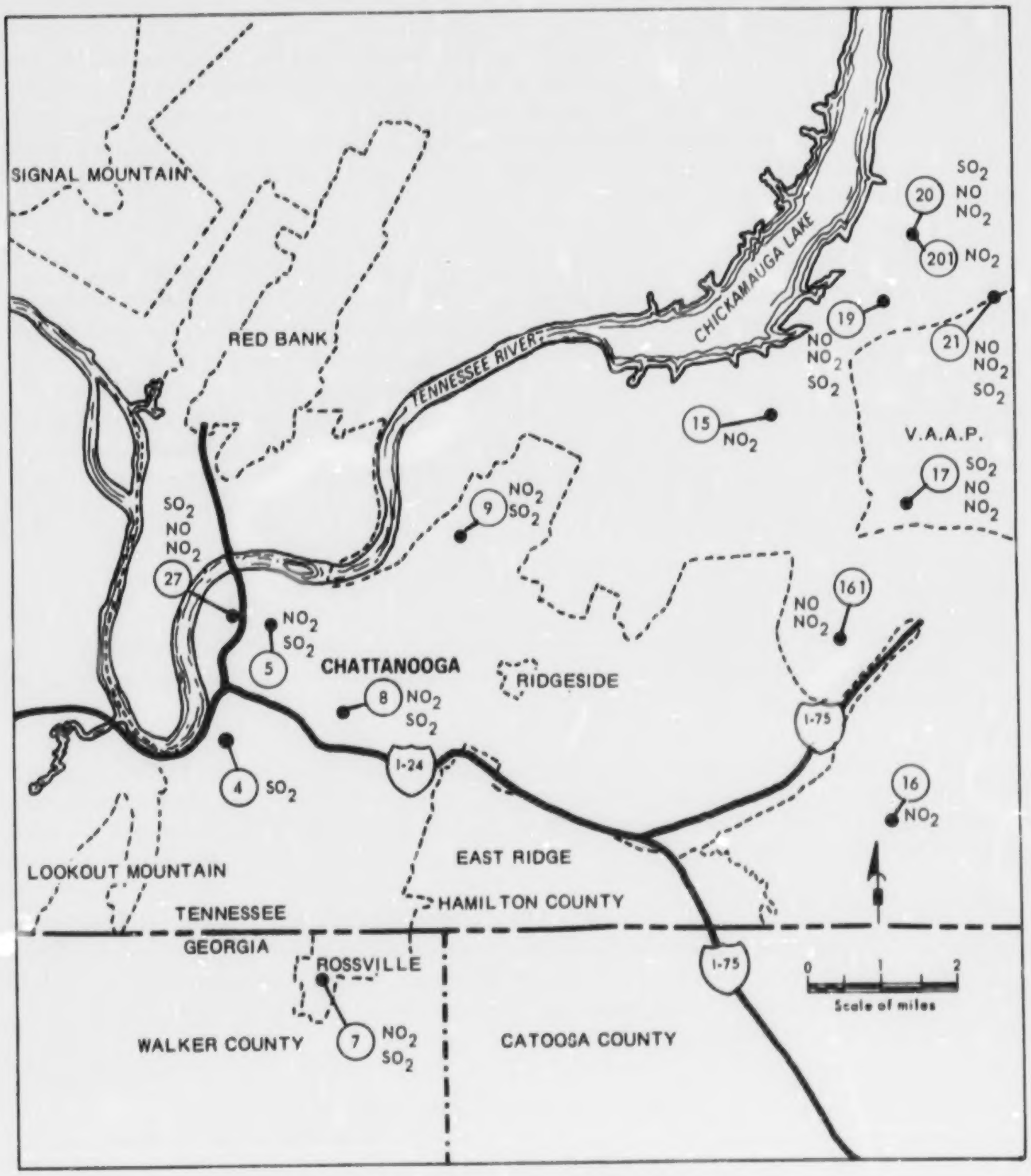

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
20 SO2 NO NO2
201 NO2
19 NO NO2 SO2
21 NO NO2 SO2
15 NO2
V.A.A.P.
17 SO2 NO NO2
9 NO2 SO2
27 SO2 NO NO2
5 NO2 SO2
CHATTANOOGA
RIDGESIDE
8 NO2 SO2
161 NO NO2
I-75
I-24
4 SO2
16 NO2
LOOKOUT MOUNTAIN
EAST RIDGE
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
I-75
0 1 2
Scale of miles
WALKER COUNTY
7 NO2 SO2
CATOOSA COUNTY

Figure 3-5. SO_2 and NO_x sampling network.

Results of the SO_2 investigations are presented in Tables 3-6 and 3-7, and graphically illustrated in Appendix C. High hourly concentrations of SO_2 were occasionally experienced in certain portions of the area: 0.58 part per million (ppm) at WDEF-TV (site #4), 1.45 ppm at VAAP-Harrison School (site #21), and 0.55 ppm at VAAP-Rod and Gun Club (site #20). Also, maximum daily averages of 0.10 ppm or greater were experienced at three locations, VAAP-Harrison School, VAAP-Rod and Gun Club, and East Chattanooga. However, the annual arithmetic mean SO_2 levels at all stations in the study area were less than or equal to 0.02 ppm.

Results of the sulfation rate studies (lead dioxide candle) are presented in Table 3-8. The highest monthly value recorded was 1.2 mg SO_3/100 cm^2-day during February 1968, at the National Guard Armory (site #6). Mean values for all stations ranged from 0.1 to 0.5 mg SO_3/100 cm^2-day. Correlation studies have shown that a factor of 0.04 applied to the sulfation result provides a good approximation of the monthly SO_2 concentrations. Converted thus, annual arithmetic mean SO_2 levels ranged from 0.002 to 0.02 ppm, estimates that check closely with actual measurements.

Adverse health effects have been noted when 24-hour average (arithmetic mean) levels of SO_2 exceed 0.11 ppm for 3 or 4 days.[9] Adverse health effects at an annual arithmetic mean of 0.04 ppm, visibility reduction to 5 miles at a mean of 0.10 ppm, adverse effects on materials at a mean of 0.12 ppm, and adverse effects on vegetation at a mean of 0.03 ppm have also been indicated.[9] It is reasonable to conclude from the measured values that while long-term SO_2 averages for the Chattanooga area are lower than the annual arithmetic mean levels defined by the Air Quality Criteria for SO_2,[9] periods of short-term, high concentrations are quite likely to occur, especially in the vicinity of the Volunteer Army Ammunition Plant.

3.3 NITROGEN OXIDES

The oxides of nitrogen, nitric oxide (NO) and nitrogen dioxide (NO_2) in particular, are significant both as toxic pollutants and as agents in the production of photochemical smog.

Nitric oxide is normally produced by the fixation of nitrogen and oxygen at high combustion temperatures. NO_2 may be produced in a secondary reaction of NO and oxygen. Both pollutants may be released directly as by-products of chemical manufacturing processes.

In the most metropolitan areas in the United States, the major sources of atmospheric nitrogen oxides (NO_x) are the high temperature combustion processes. The Chattanooga area, however, is unique because, besides combustion sources, nitrogen oxides are released in large quantities in the manufacture of 2, 4, 6 trinitrotoluene (TNT) and related chemical products.

To record ground level concentrations of both NO and NO_2 in the area, measurements were taken continuously at numerous sites throughout the area. The colorimetric Saltzman technique[10] was employed at all stations. Sampling locations are shown on Figure 3-5 and listed by station in Appendix B.

Table 3-6. CUMULATIVE FREQUENCY DISTRIBUTION OF 1- AND 2-HOUR SO_2 CONCENTRATIONS

Station number	Method	Operating period	Number observations	Concentration, ppm											
				Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
				90	75	50	25	10	1						
4	a	10/67 - 2/68	661	<0.01	0.01	0.02	0.02	0.04	0.07	0.58	<0.01	0.02	0.02	0.01	2.2
5	b	9/67 - 3/68	3,901	0.01	0.01	0.02	0.03	0.04	0.10	0.19	<0.01	0.02	0.02	0.02	1.9
5	a	4/68 - 5/68	291	<0.01	<0.01	0.01	0.02	0.02	0.04	0.04	<0.01	0.01	0.01	0.01	1.9
7	b	10/67 - 11/68	6,455	0.01	0.01	0.01	0.02	0.03	0.05	0.11	<0.01	0.01	0.01	0.01	1.7
8	b	9/67 - 12/67	1,118	<0.01	0.01	0.01	0.02	0.03	0.04	0.06	<0.01	0.01	0.01	0.01	1.7
8	a	10/67	85	<0.01	<0.01	<0.01	0.02	0.02	-	0.05	<0.01	0.01	0.01	0.01	2.1
9	a	10/67 - 5/68	1,172	<0.01	0.01	0.01	0.02	0.04	0.08	0.25	<0.01	0.02	0.02	0.01	2.3
17	c	2/68 - 11/68	7,003	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.34	<0.01	<0.01	0.01	<0.01	1.3
19	c	5/68 - 11/68	4,722	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.11	<0.01	<0.01	<0.01	<0.01	1.3
20	c	1/68 - 11/68	7,915	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.55	<0.01	<0.01	0.01	<0.01	1.4
21	c	1/68 - 11/68	7,864	<0.01	<0.01	<0.01	<0.01	0.01	0.08	1.45	<0.01	<0.01	0.03	0.01	1.8
27	b	4/68 - 11/68	4,682	<0.01	0.01	0.01	0.01	0.02	0.03	0.09	<0.01	0.01	0.01	0.01	1.6

[a] 2 hr averages, WG & P wet impinger method.
[b] 1 hr averages, conductivity method.
[c] 1 hr averages, WG & P colorimetric method.

Table 3-7. CUMULATIVE FREQUENCY DISTRIBUTION OF DAILY SO_2 CONCENTRATIONS

Station number	Method	Operating period	Number observations	Concentration, ppm										
				Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
				90	75	50	25	10	1						
4	a	10/67 - 2/68	58	<0.01	0.01	0.01	0.02	0.03	-	0.06	<0.01	0.02	0.01	0.02	2.1
5	b	9/67 - 3/68	173	<0.01	0.01	0.02	0.02	0.03	-	0.09	<0.01	0.02	0.01	0.02	2.5
5	a	4/68 - 5/68	28	<0.01	<0.01	0.01	0.01	0.01	-	0.02	<0.01	0.01	<0.01	0.01	2.0
7	b	10/67 - 11/68	297	<0.01	<0.01	0.01	0.02	0.02	0.04	0.04	<0.01	0.01	0.01	0.01	3.0
8	b	9/67 - 12/67	53	<0.01	<0.01	0.01	0.02	0.02	-	0.03	<0.01	0.02	0.01	0.01	2.8
8	a	11/67	8	Insufficient data						0.05	<0.01	-	-	-	-
9	a	10/67 - 5/68	104	<0.01	0.01	0.01	0.02	0.03	0.12	0.12	<0.01	0.02	0.02	0.01	2.3
17	c	2/68 - 11/68	295	93% of values were zero						0.05	<0.01	<0.01	-	-	-
19	c	5/68 - 11/68	201	95% of values were zero						0.02	<0.01	<0.01	-	-	-
20	c	1/68 - 11/68	335	91% of values were zero						0.10	<0.01	<0.01	-	-	-
21	c	1/68 - 11/68	334	79% of values were zero						0.19	<0.01	<0.01	-	-	-
27	b	4/68 - 11/68	220	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.03	<0.01	0.01	<0.01	0.01	2.7

[a] 2 hr averages, WG & P wet impinger method.
[b] 1 hr averages, conductivity method.
[c] 1 hr averages, WG & P colorimetric method.

Table 3-8. MONTHLY SULFATION CONCENTRATIONS
(mg $SO_3/100\ cm^{-2}$-day)

Station number	Operating period	Number observations	Minimum value	Maximum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
1	10/67 - 11/68	14	<0.1	0.5	0.2	0.2	0.2	2.2
2	10/67 - 11/68	14	<0.1	0.5	0.2	0.1	0.2	2.1
3	10/67 - 11/68	14	<0.1	0.4	0.1	0.1	0.1	2.3
4	10/67 - 11/68	14	<0.1	0.7	0.3	0.2	0.2	2.6
6	10/67 - 11/68	14	<0.1	0.5	0.3	0.2	0.3	2.2
7	10/67 - 11/68	14	<0.1	0.5	0.2	0.2	0.1	2.4
8	10/67 - 11/68	14	0.1	1.2	0.5	0.3	0.4	1.9
9	10/67 - 11/68	14	<0.1	0.7	0.3	0.2	0.2	2.3
10	10/67 - 11/68	14	<0.1	0.5	0.2	0.2	0.1	2.6
11	10/67 - 11/68	14	<0.1	0.5	0.2	0.2	0.1	2.5
12	11/67 - 11/68	13	<0.1	0.5	0.1	0.2	0.1	2.6
13	10/67 - 11/68	14	<0.1	0.3	0.1	0.1	0.1	1.9
14	10/67 - 11/68	14	<0.1	0.6	0.2	0.2	0.2	2.5
15	10/67 - 11/68	14	<0.1	0.5	0.1	0.2	0.1	2.4
16	10/67 - 3/68	6	0.1	0.4	0.2	0.1	0.2	1.8
18	10/67 - 11/68	14	<0.1	0.3	0.2	0.1	0.1	2.1
22	12/67 - 11/68	12	0.1	0.7	0.4	0.2	0.4	1.8
24	12/67 - 11/68	11	<0.1	0.8	0.2	0.3	0.1	2.9
25	6/68 - 11/68	6	<0.1	0.1	<0.1	<0.1	<0.1	1.3
27	5/68 - 11/68	7	0.2	0.5	0.4	0.1	0.3	1.4
28	4/68 - 11/68	7	<0.1	0.3	0.2	0.1	0.2	1.9
107E	10/67 - 11/68	13	<0.1	0.4	0.2	0.1	0.2	2.1
108E	10/67 - 11/68	13	<0.1	0.4	0.2	0.1	0.1	2.0
109E	10/67 - 11/68	13	<0.1	0.3	0.1	0.1	0.1	1.9
110E	10/67 - 11/68	13	<0.1	0.2	0.1	0.1	0.1	1.8
140E	10/67 - 11/68	14	<0.1	1.0	0.4	0.4	0.2	2.3
141E	10/67 - 11/68	14	<0.1	0.5	0.2	0.2	0.1	2.4

3.3.1 Nitrogen Dioxide

Frequency distributions of the daily and hourly NO_2 samples are presented graphically in Appendix C and in Tables 3-9 and 3-10. Average concentrations for the study period are presented in the bar graphs of Figure 3-6. These results indicate that the seven sampling stations near the Volunteer Army Ammunition Plant experienced arithmetic mean concentrations at least twice as large as those of the remaining four locations. A mean concentration of 0.21 ppm was measured at VAAP-Pond (site #19), while concentration of 0.14 and 0.16 ppm were experienced at the two Rod and Gun Club stations (sites #20 and #201). By comparison, downtown Chattanooga experienced an arithmetic mean concentration of only 0.04 ppm at both the Federal Building (site #5) and the Golden Gateway (site #27). In Georgia, Rossville (site #7) had a similar arithmetic mean of 0.04 ppm.

When the arithmetic mean NO_2 results obtained in the Chattanooga area were compared to those of the seven CAMP stations[12] in the United States, values obtained at the stations in the vicinity of the ammunition plant appeared significantly higher than any of the CAMP locations. Downtown Chattanooga and Rossville values were of the same magnitude or less than the CAMP locations, (0.03 to 0.06 ppm).

Hourly NO_2 concentrations in excess of 2.00 ppm were observed at sites #17, #19, #20, #21, and #201, each highly influenced by the ammunition plant. These values differ from those recorded in downtown Chattanooga by an order of magnitude.

A daily maximum NO_2 concentration of 1.00 ppm was measured at the VAAP-Pond (site #19), and a daily concentration of 0.91 ppm at the VAAP-Rod and Gun Club (site #20). These values are again much greater than those in downtown Chattanooga.

In an attempt to define possible episode periods, the duration of NO_2 concentrations were tabulated for concentrations of 0.25, 0.50, and 1.0 ppm (Table 3-11). The table shows the number of cases at each station when the concentration levels were exceeded for a minimum of 8 hours. There were 71 separate cases when NO_2 levels in excess of 0.25 ppm existed for at least 8 hours at site #20. Of these, 29 had levels in excess of 0.50 ppm for at least 8 hours. Sites #20, #201, and #19 each had one recorded instance where a concentration of at least 1.0 ppm existed for at least eight consecutive hours. Those stations at a greater distance from the ammunitions plant (sites #5, #7, #27, and #16) recorded no 8-hour cases in excess of 0.25 ppm.

The sampling results clearly indicate that a definite NO_2 problem does exist in the Chattanooga area, especially in the vicinity of the Volunteer Army Ammunition Plant. Levels of NO_2 found in the studies are certainly of sufficient magnitude to warrant concern by area residents.

3.3.2 Nitric Oxide

Frequency distributions of hourly NO sampling results are given in Table 3-12. Maximum hourly averages ranged from 2.75 ppm at the VAAP-Harrison School, (site #21), to 0.36 ppm at the Golden Gateway, (site #27). Arithmetic mean concentrations ranged from a maximum of 0.11 ppm at VAAP-Pond, (site

Table 3-9. CUMULATIVE FREQUENCY DISTRIBUTION OF HOURLY NO_2 CONCENTRATIONS

Station number	Operating period	Number observations	Concentration, ppm											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
5	12/67 - 3/68	1,823	0.02	0.03	0.04	0.05	0.07	0.09	0.16	<0.01	0.04	0.02	0.03	1.7
7	4/68 - 11/68	5,044	0.01	0.02	0.03	0.05	0.09	0.17	0.26	<0.01	0.04	0.04	0.03	2.3
15	12/67 - 11/68	7,465	0.01	0.02	0.05	0.08	0.16	0.60	1.80	<0.01	0.08	0.11	0.04	3.1
16	12/67 - 3/68	2,126	<0.01	0.01	0.02	0.03	0.05	0.18	0.47	<0.01	0.03	0.04	0.02	2.4
17	2/68 - 11/68	6,970	<0.01	<0.01	0.02	0.07	0.26	1.10	2.45	<0.01	0.09	0.21	0.02	4.9
19	5/68 - 11/68	4,717	<0.01	<0.01	0.04	0.22	0.64	1.75	3.80	<0.01	0.21	0.38	0.05	6.3
20	9/67 - 11/68	10,607	<0.01	0.01	0.03	0.12	0.46	1.42	3.80	<0.01	0.14	0.30	0.04	5.2
21	9/67 - 11/68	10,724	<0.01	0.01	0.02	0.10	0.25	0.90	2.66	<0.01	0.09	0.18	0.03	4.4
27	4/68 - 11/68	3,741	0.01	0.02	0.03	0.05	0.07	0.11	0.89	<0.01	0.04	0.03	0.03	2.1
161	4/68 - 11/68	5,136	0.01	0.01	0.03	0.07	0.17	0.77	1.55	<0.01	0.08	0.14	0.03	3.3
201	12/67 - 5/68	2,615	<0.01	0.01	0.03	0.14	0.53	1.50	3.00	<0.01	0.16	0.31	0.04	4.9

Table 3-10. CUMULATIVE FREQUENCY DISTRIBUTION OF DAILY NO_2 CONCENTRATIONS

Station number	Operating period	Number observations	Concentration, ppm											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
5	12/67 - 3/68	95	0.02	0.02	0.03	0.05	0.06	-	0.08	0.01	0.04	0.02	0.04	1.7
7	4/68 - 11/68	233	0.01	0.02	0.03	0.05	0.07	0.12	0.13	0.01	0.04	0.02	0.03	2.1
15	12/67 - 11/68	341	0.02	0.03	0.06	0.10	0.15	0.28	0.44	<0.01	0.08	0.06	0.06	2.4
16	12/67 - 3/68	96	<0.01	0.01	0.02	0.04	0.05	-	0.09	<0.01	0.03	0.02	0.02	3.3
17	2/68 - 11/68	295	<0.01	<0.01	0.05	0.14	0.26	0.51	0.64	<0.01	0.10	0.12	0.05	3.8
19	5/68 - 11/68	202	<0.01	0.04	0.13	0.30	0.49	0.78	1.00	<0.01	0.21	0.20	0.10	3.0
20	9/67 - 11/68	456	<0.01	0.02	0.09	0.22	0.36	0.62	0.91	<0.01	0.15	0.16	0.07	3.1
21	9/67 - 11/68	457	<0.01	0.02	0.06	0.13	0.22	0.39	0.47	<0.01	0.09	0.09	0.05	3.1
27	4/68 - 11/68	201	0.01	0.02	0.03	0.04	0.06	0.08	0.08	0.01	0.04	0.02	0.03	1.9
161	4/68 - 11/68	230	0.01	0.02	0.04	0.09	0.17	0.38	0.40	0.01	0.08	0.07	0.05	2.8
201	12/67 - 5/68	128	0.01	0.02	0.07	0.26	0.46	0.70	0.83	<0.01	0.16	0.19	0.08	5.0

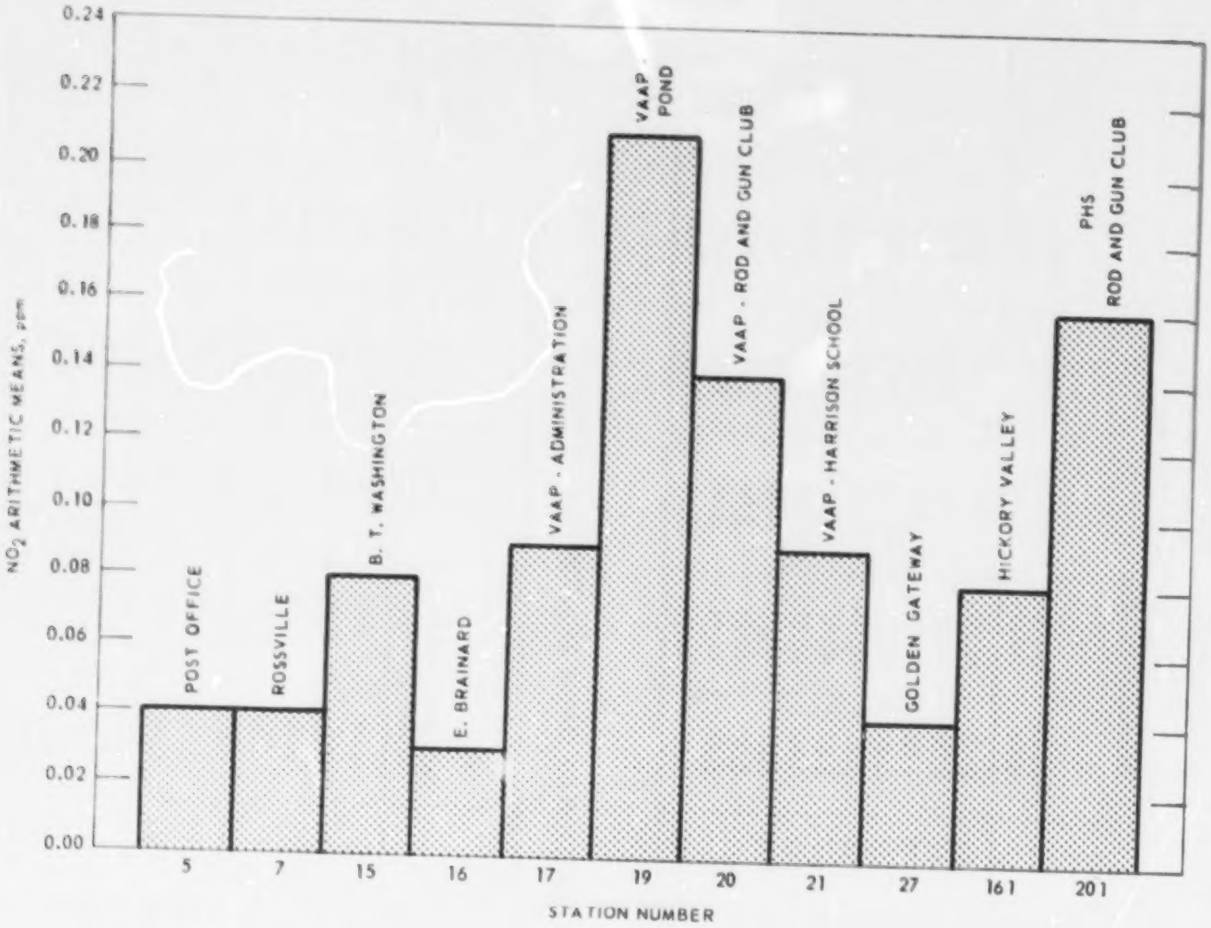


Figure 3-6. Comparison of the arithmetic mean nitrogen dioxide concentration (ppm) for all sampling stations, October 1967 - November 1968.

Table 3-11. EPISODES OF HIGHLY HOURLY NO_2 CONCENTRATIONS LASTING 8 OR MORE HOURS

Station number	Number of episodes exceeding stated values, ppm		
	0.25	0.50	1.0
20	71	29	1
19	60	28	1
201	24	10	1
17	19	4	0
21	18	2	0
161	8	0	0
15	4	0	0
27	0	0	0
7	0	0	0
16	0	0	0
5	0	0	0

#19) to 0.03 ppm at the Golden Gateway; in other words the ammunition plant area experiences much higher mean concentrations and maximums than the downtown Chattanooga area.

Table 3-12. CUMULATIVE FREQUENCY DISTRIBUTION OF HOURLY NO CONCENTRATIONS

Station number	Operating period	Number observations	Concentration, ppm											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
17	5/68 - 11/68	4,611	<0.01	<0.01	0.01	0.06	0.20	0.59	1.10	<0.01	0.06	0.12	0.02	4.4
19	7/68 - 11/68	3,174	<0.01	<0.01	0.02	0.14	0.33	0.77	1.53	<0.01	0.11	0.17	0.03	5.7
20	9/67 - 11/68	10,678	<0.01	<0.01	<0.01	0.06	0.26	0.79	2.15	<0.01	0.08	0.17	0.02	5.0
21	9/67 - 11/68	10,720	<0.01	<0.01	<0.01	0.05	0.16	0.66	2.75	<0.01	0.06	0.14	0.02	4.4
27	6/68 - 11/68	2,292	<0.01	<0.01	0.01	0.03	0.07	0.22	0.36	<0.01	0.03	0.04	0.02	2.8
161	6/68 - 11/68	3,756	<0.01	<0.01	0.02	0.06	0.12	0.35	0.71	<0.01	0.05	0.07	0.02	3.4

Concentrations presented in Table 3-12 also indicate that substantial amounts of colorless NO are released from chemical manufacture east of Missionary Ridge. When these high NO levels are combined with NO_2 levels previously reported, total ambient concentrations of nitrogen oxides in the area exceeded 4.0 ppm.

3.4 OXIDANTS

Oxidants are a class of gaseous pollutants primarily derived from a photochemical reaction involving unburned hydrocarbons and nitrogen oxides. Sunshine provides the energy to affect a reaction between these constituants to form ozone, peroxyacyl nitrate, and other oxidant radicals. These oxidants are important because they can cause rubber to crack, damage vegetation, and irritate the eyes, throat, and lungs.

In the Chattanooga area, hourly oxidant measurements were recorded at eight locations. Mast* coulometric analyzers were used at seven stations and a Beckman colorimetric analyzer was used at the eighth (site #27).

Results from these investigations are summarized in Table 3-13. These results generally indicate that overall oxidant levels in the study area are low, with the exception of the area near the Volunteer Army Ammunition Plant (site #201), where high readings are attributable to the large amount of NO and NO_2 present in the area.

3.5 HYDROCARBONS

Hydrocarbons are emitted during the incomplete combustion of all fuels. Air pollution control engineers are concerned with these emissions primarily because of their relationship to the production of photochemical smog. As an important constituent of photochemical smog, their presence in the ambient atmosphere along with sunlight indicates a potential oxidant pollution.

This class of pollutants was only measured for a limited time during the study period, at the Golden Gateway (site #27) from June to November 1968. The results from this investigation, presented in Table 3-14, are of the same magnitude as those monitored in the seven CAMP stations for the period 1962 to 1966. Because of the limited amount of sampling in the Chattanooga area, no area-wide conclusion can be drawn.

3.6 CARBON MONOXIDE

Carbon monoxide (CO) is a colorless, odorless gas, resulting chiefly from the incomplete combustion of carbonaceous materials. It is important as an air pollutant because of its extremely high affinity for blood hemoglobin. Motor vehicles are the principal emitters, although foundries and open burning also contribute.

Sampling for CO in the Chattanooga area was limited. One-hour concentrations were measured by the infrared absorption technique, at Rossville (site #7) during the period of October 1967 to March 1968 and at the Golden Gateway

---

*Mention of a company or product name does not constitute endorsement by the U.S. Department of Health, Education, and Welfare.

Table 3-13. CUMULATIVE FREQUENCY DISTRIBUTION OF HOURLY OXIDANT CONCENTRATIONS

Station number	Operating period	Number observations	Concentration, ppm											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
5	1/68 - 5/68	3,083	0.01	0.01	0.02	0.03	0.03	0.05	0.06	0.01	0.02	0.01	0.02	0.02
7	11/67 - 5/68	3,103	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.01	0.02
8	1/68 - 3/68	1,249	0.01	0.01	0.02	0.02	0.04	0.03	0.04	0.01	0.02	0.01	0.01	0.02
9	4/68 - 5/68	1,030	0.01	0.01	0.02	0.04	0.04	0.06	0.07	0.01	0.02	0.02	0.02	0.02
15	12/67 - 4/68	2,346	0.01	0.01	0.02	0.03	0.04	0.06	0.16	0.01	0.02	0.02	0.02	0.02
16	11/67 - 3/68	2,699	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.01	0.02
201	4/68 - 5/68	1,189	0.01	0.02	0.03	0.04	0.05	0.15	0.22	0.01	0.03	0.02	0.02	0.02
27	5/68 - 11/68	2,871	0.01	0.01	0.01	0.04	0.07	0.11	0.20	0.01	0.02	0.03	0.01	0.09

Table 3-14. CUMULATIVE FREQUENCY DISTRIBUTION OF HOURLY HYDROCARBON CONCENTRATIONS

Station number	Operating period	Number observations	Concentration, ppm											
			Occurrence frequency, percentile						Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
			90	75	50	25	10	1						
27	6/68 - 11/68	2,456	1.0	1.3	1.9	2.7	3.9	8.9	16.5	0.1	2.3	1.7	1.8	2.2

(site #27) during the period from March 1968 to December 1968. Results from these investigations are summarized in Table 3-15.

Arithmetic mean CO concentrations obtained at Rossville and the Golden Gateway were 3.4 and 2.4 ppm, respectively; both values are below the arithmetic mean concentrations measured at the six of the seven CAMP stations for the period 1962 to 1966.

Because of the limited amount of sampling conducted during the study period, no conclusion can be drawn as to the extent of area-wide CO pollution.

3.7 CHEMICAL ANALYSES OF SUSPENDED PARTICULATE

Selected samples of suspended particulates from eight stations (sites #4, #5, #7, #14, #17, #19, #20, and #21) were colorimetrically analyzed for sulfate, ammonium, and nitrate. Concentration values and sample percentages can be found in Table 3-16. Respirable particulates at sites #4, #5, and #7, are also included.

3.7.1 Sulfate

High-volume suspended particulate samples from the eight selected sampling stations, and respirable dust samples from three stations (sites #4, #5, and #7), were analyzed for sulfate by the methylthymol blue method. Arithmetic mean results of these analyses are summarized in Table 3-16. When compared with the 1966 National Air Sampling Network (NASN)[12] urban arithmetic average of 10.7 μg/m^3, concentrations in the downtown Chattanooga valley (sites #4, #5, and #7) were less than, while concentrations in the vicinity of the Volunteer Army Ammunition Plant were in excess of, the National average. Maximum sulfate concentrations were recorded at VAAP-Harrison School (site #21) where the daily arithmetic mean was 21.7 μg/m^3. These observations reflect the influence of an adjacent sulfuric acid manufacturing plant.

Frequency distributions for all sulfate analyses are presented in Table 3-17. According to the 1965 NASN standards[12] the ammunition plant area experienced instances of severe particulate sulfate pollution at least one-fourth of the time. Locally, the 50 percentile values measured near the plant were at least twice as large as those in the downtown Chattanooga valley area.

3.7.2 Ammonium

High-volume and respirable dust samples from the same stations were analysed for ammonium by the indophenol method. Arithmetic mean results from the analyses are summarized in Table 3-16.

When the results in Table 3-16 are compared to 1965 NASN data, arithmetic mean values in the vicinity of the ammunition plant are, again, significantly higher than the NASN arithmetic mean average of 0.6 μg/m^3. High averages at the VAAP-Pond (site #19) and the VAAP-Rod and Gun Club (site #20), 17.6 and 12.1 μg/m^3, respectively, reflect the strong influence of nitric acid manufacture upwind from these sampling sites.

Table 3-15. CUMULATIVE FREQUENCY DISTRIBUTION OF HOURLY CARBON MONOXIDE CONCENTRATIONS

			Concentration, ppm											
			Occurrence frequency, percentile											
Station number	Operating period	Number observations	90	75	50	25	10	1	Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
7	10/67 - 3/68	2,660	1.1	2.0	3.1	4.5	6.1	10.3	15.6	0.1	3.4	2.1	2.7	2.2
27	4/68 - 11/68	3,383	0.3	1.2	2.1	3.3	4.6	7.3	15.7	0.1	2.4	1.7	1.6	3.0

Table 3-16. COLORIMETRIC ANALYSES OF SELECTED SUSPENDED PARTICULATE AND RESPIRABLE DUST SAMPLES

		Arithmetic mean concentration, $\mu g/m^3$					Percentage of total		
		Total		Fraction					
Station number	Location	Respirable dust	Suspended particulate	Sulfate	Ammonium	Nitrate	Sulfate	Ammonium	Nitrate
4	WDEF-TV	-	106.2	9.2	1.1	2.5	8.7	1.0	2.4
		48.8	-	9.1	1.4	1.6	18.6	2.9	3.3
5	Post Office	-	110.0	8.7	1.2	2.4	8.7	1.1	2.2
		44.7	-	9.1	1.8	1.9	20.4	4.0	4.2
7	Rossville	-	117.9	9.1	0.7	2.7	7.7	0.6	2.3
		42.7	-	8.4	1.0	1.2	19.7	2.3	2.8
14	Lovell Field	-	79.8	10.6	1.1	3.8	13.3	1.4	4.7
17	VAAP-Administration	-	140.5	18.7	4.5	19.9	13.3	3.2	14.2
19	VAAP-Pond	-	146.5	18.2	17.6	48.9	12.4	12.0	33.4
20	VAAP-Rod and Gun Club	-	111.1	17.3	12.1	37.4	15.6	10.9	33.7
21	VAAP-Harrison School	-	87.5	21.7	6.8	13.2	24.8	7.8	15.1

Table 3-17. CUMULATIVE FREQUENCY DISTRIBUTION OF SUSPENDED SULFATE (SO_4) PARTICULATE

Station number	Location	Operating period	Number observations	Concentration, $\mu g/m^3$									
				Occurrence frequency, percentile					Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean
				90	75	50	25	10					
4	WDEF-TV	12/67 11/68	92	4.2	6.1	8.2	12.0	15.3	21.3	1.5	9.2	4.2	8.2
5	Post Office	12/67 - 11/68	82	3.9	5.5	7.6	11.1	14.2	24.6	2.1	8.7	4.2	7.8
7	Rossville	12/67 - 11/68	85	4.5	6.0	8.5	11.4	14.4	22.2	3.1	9.1	3.8	8.4
14	Lovell Field	12/67 - 11/68	81	3.9	5.9	8.7	13.9	17.4	54.8	1.7	10.6	7.7	8.7
17	VAAP-Administration	8/68 - 11/68	38	5.9	10.5	16.5	21.7	45.4	60.6	3.8	18.7	11.5	15.7
19	VAAP-Pond	8/68 - 11/68	38	6.5	9.8	18.0	24.8	33.2	36.4	2.0	18.2	9.4	15.4
20	VAAP-Rod and Gun Club	8/68 - 11/68	39	6.6	9.5	17.0	23.6	28.4	35.1	5.1	17.3	8.6	15.1
21	VAAP-Harrison School	8/68 - 11/68	39	5.9	11.0	19.0	30.5	42.6	61.7	2.6	21.7	14.0	17.3

A frequency distribution of ammonium is presented in Table 3-18. On the basis of 1966 NASN standards, severe instances of suspended particulate ammonium pollution occurred as much as 25 percent of the time in the vicinity of the ammunition plant. Downtown Chattanooga, on the other hand, did not experience such episodes.

3.7.3 Nitrate

High-volume and respirable dust samples were analyzed for nitrate by hydrazine reduction and diazotization. Results from these analyses are presented in Tables 3-16 and 3-19, which show a severe nitrate problem in the vicinity of the ammunition plant. In 1965, the NASN National urban arithmetic average was 2.9 $\mu g/m^3$ and the maximum station average, 13.5 $\mu g/m^3$. At all stations (#17, #19, #20, and #21) near the plant, arithmetic mean values exceeded the NASN maximum station average. At the VAAP-Pond (site #19), a maximum daily arithmetic average of 48.9 $\mu g/m^3$ was recorded—more than three times greater than the maximum NASN station, and approximately 20 times greater than the downtown Chattanooga concentration.

3.8 SUMMARY

Air quality measurements conducted in the Chattanooga - Rossville study area during 1967 and 1968 indicated:

1. A suspended particulate problem existed in the area, with two centers of maximum concentration—the downtown Chattanooga - Rossville valley and the Volunteer Army Ammunitions Plant (VAAP). At the majority of sampling sites, concentrations exceeded Criteria[11] levels for adverse material effects (60 $\mu g/m^3$), for adverse health effects (80 $\mu g/m^3$), and for visibility reduction (150 $\mu g/m^3$). For the 21 sites involved, the material effects level was exceeded at least 50 percent of the time at 15 sites; the health effects level, at least 50 percent of the time at nine sites; and the visibility level, 25 percent of the time at four sites. The maximum observed concentrations were 697 $\mu g/m^3$ at the National Guard Armory (site #8) and 586 $\mu g/m^3$ at the VAAP Pond (site #19).

2. In the downtown Chattanooga - Rossville valley approximately 40 percent of the suspended particulate pollution was respirable in nature. In the vicinity of the ammunition plant, as much as 75 percent of the material may have been respirable.

3. Soiling index measurements revealed a definite soiling problem in the downtown Chattanooga - Rossville valley. Recorded measurements, on occasion, exceeded 9.0 Coh per 10^3 lineal feet at three sites (#5, #8, and #9). The State of Tennessee industrial area limitations standard (5.0 Coh per 10^3 lineal feet, not to be exceeded 1 percent of the time during any 30-day period) was frequently exceeded at four sites (#5, #7, #8, and #9).

4. Concentrations of nitrogen oxides (NO_x) were found to be extremely high in the vicinity of the ammunition plant. The VAAP-Pond (site #19) experienced a maximum hourly NO_2 concentration of 3.8 ppm, a maximum daily NO_2 concentration of 1.0 ppm, and a 7-month arithmetic mean

Table 3-18. CUMULATIVE FREQUENCY DISTRIBUTION OF SUSPENDED AMMONIUM (NH_4) PARTICULATE

Station number	Location	Operating period	Number observations	Concentration, $\mu g/m^3$									
				Occurrence frequency, percentile					Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean
				90	75	50	25	10					
4	WDEF-TV	12/67 - 11/68	92	0.1	0.3	0.7	1.6	2.6	5.5	0.0	1.1	1.1	0.7
5	Post Office	12/67 - 11/68	82	0.1	0.3	1.0	1.6	2.6	4.6	0.0	1.2	1.0	0.8
7	Rossville	12/67 - 11/68	85	0.1	0.2	0.4	0.9	1.8	2.9	0.0	0.7	0.7	0.4
14	Lovell Field	12/67 - 11/68	81	0.1	0.2	0.4	1.2	2.0	14.4	0.0	1.1	1.9	0.5
17	VAAP-Administration	8/68 - 11/68	37	0.5	1.7	3.5	6.3	8.6	16.6	0.0	4.5	3.8	2.8
19	VAAP-Pond	8/68 - 11/68	38	0.2	1.2	6.2	14.0	55.2	110.3	0.0	17.6	28.6	4.3
20	VAAP-Rod and Gun Club	8/68 - 11/68	39	0.3	0.9	2.3	10.6	46.5	64.6	0.0	12.1	20.0	2.8
21	VAAP-Harrison School	8/68 - 11/68	39	0.4	1.2	3.8	10.1	18.0	35.1	0.0	6.8	8.1	3.1

Table 3-19. CUMULATIVE FREQUENCY DISTRIBUTION OF SUSPENDED NITRATE (NO_3) PARTICULATE

Station number	Location	Operating period	Number observations	Concentration, $\mu g/m^3$									
				Occurrence frequency, percentile					Maximum value	Minimum value	Arithmetic mean	Standard deviation	Geometric mean
				90	75	50	25	10					
4	WDEF-TV	12/67 - 11/68	92	1.1	1.8	2.5	3.2	4.0	5.6	0.0	2.5	1.2	2.2
5	Post Office	12/67 - 11/68	82	0.8	1.6	2.1	2.8	4.0	7.5	0.0	2.4	1.3	2.0
7	Rossville	12/67 - 11/68	85	1.1	1.6	2.4	3.4	4.3	11.9	0.3	2.7	1.6	2.3
14	Lovell Field	12/67 - 11/68	80	0.5	1.5	2.9	5.0	8.5	21.4	0.3	3.8	3.4	2.6
17	VAAP-Administration	8/68 - 11/68	38	2.5	6.0	17.6	29.0	44.8	57.8	0.6	19.9	16.0	12.7
19	VAAP-Pond	8/68 - 11/68	38	1.4	3.4	22.0	46.7	124.8	377.6	0.4	48.9	84.2	13.8
20	VAAP-Rod and Gun Club	8/68 - 11/68	39	1.0	2.4	8.7	41.5	144.4	232.2	0.3	37.4	64.6	8.1
21	VAAP-Harrison School	8/68 - 11/68	39	0.9	2.2	5.5	16.5	40.8	94.1	0.3	13.2	43.2	4.1

NO_2 concentration of 0.21 ppm. Combined NO_x averages greater than 4.0 ppm were found to occur in the area. All of these exceeded the 1966 CAMP averages.

5. The measured, long-term arithmetic mean SO_2 concentrations are lower than the National standard minimum for adverse effects. Periods of short-term, high concentrations, however, did occur, particularly in the vicinity of the ammunition plant, east of Missionary Ridge.

6. Limited sampling of oxidants, hydrocarbons, and carbon monoxide indicated pollutant levels comparable to the mean National levels measured at CAMP stations.[11]

7. Colorimetric analysis of selected high volume suspended particulate samples and respirable dust samples showed that sulfate concentrations in the area east of Missionary Ridge were in excess of the National CAMP averages.[9] Severe instances of suspended particulate ammonium pollution occurred as much as 25 percent of the time in the same vicinity. Nitrate pollution in the area was 4 to 12 times the national CAMP average[9] and up to 20 times the average for downtown Chattanooga.

BLANK PAGE

4. MATERIAL EFFECTS INVESTIGATIONS

The National Air Pollution Control Administration has maintained an Interstate Surveillance Project (ISP) in the form of a network of uniform static monitoring devices (effect packages) located throughout the United States, as a means of relating air quality to material effects of air pollutants.[9] Six such stations were located in the metropolitan Chattanooga area (see Figure 4-1) and measurements from these stations, used as a basis for estimating the effects of air pollutants on materials in the general area.

Frequency distributions of 1967 and 1968 annual averages for the entire Interstate Surveillance Project[13] network have also been presented to provide a base for comparison between Chattanooga area stations and stations located elsewhere throughout the United States.

4.1 METAL CORROSION

The combination of SO_2 and acid aerosols in moist air is a prime factor in metal corrosion processes. Zinc and steel plates were exposed in the Chattanooga area in order to determine the rate and the intensity of atmospheric corrosion. Annual and 3-month average rates were calculated by exposing three plates, two steel and one zinc, at six locations. The steel plates were left for 3 and 13 months, respectively; the zinc, for 12 months.

The degree of corrosion was measured by the weight-loss method, but reported in penetration-depth units. Zinc was chosen because, of the non-ferrous metals, it exhibits the least resistance to atmospheric corrosion. Zinc, however, is more resistant than ferrous metals such as steel.

Results in microns per year (μ/yr) for 1967 and 1968 are summarized in Table 4-1. For comparison Table 4-2 presents a cumulative frequency distribution of all ISP corrosion rates. At all six locations, zinc consistently exceeded the National 50 percentile rate. Steel exceeded or approximated that level in 1967 but was slightly less in 1968. All corrosion rates at VAAP-Pond 5 (site #107) greatly exceeded both the rates at the other five sites and those in the top quartile of ISP stations. In 1968, zinc corrosion at this site was in the top 1 percent, Nationally. Sites #109 and #110, and #140 were also in the top quartile of annual zinc corrosion for the year 1968.

4.2 COLOR FADING IN DYED FABRICS

Five different cloth fabric panels were exposed in the absence of sunlight, for 90-day periods during 1967 and 1968. Four of the fabrics selected were sensitive to air pollutants such as SO_2, NO_x, or ozone, and the fifth, relatively resistant to fading, was used as a control fabric. Fabric 1 was sensitive to a combination of air pollutants, fabric 3 to NO_x, fabric 4 and 5 to ozone, and fabric 2, the control fabric, was primarily sensitive to soiling.

The fabric panels were analyzed with a photoelectric color differentiating instrument that measures light reflected at a 45-degree angle from the cloth

Preceding page blank

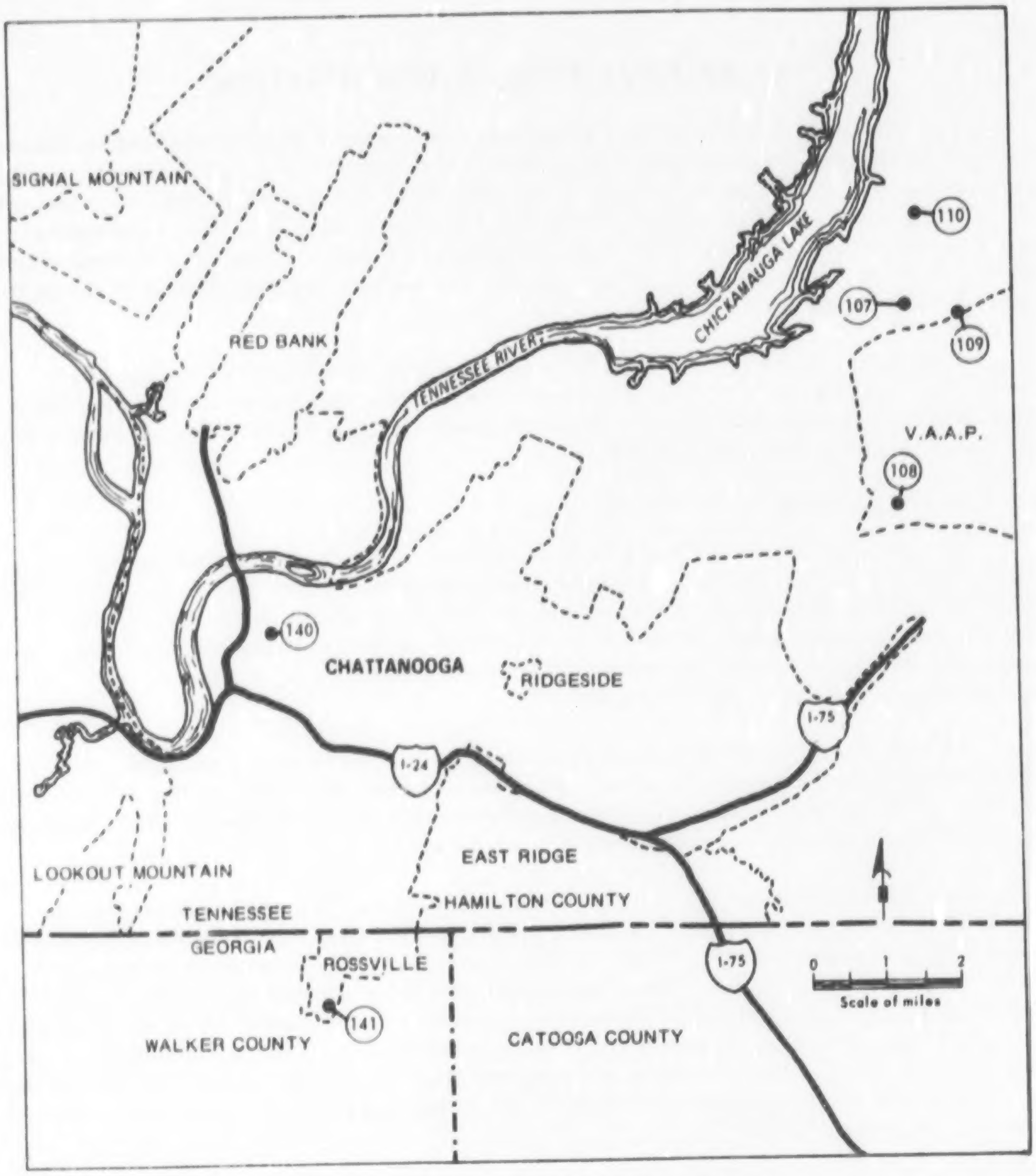

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
110
107
109
V.A.A.P.
108
140
CHATTANOOGA
RIDGESIDE
I-75
I-24
EAST RIDGE
LOOKOUT MOUNTAIN
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
141
WALKER COUNTY
CATOOSA COUNTY
I-75
0
1
2
Scale of miles

Figure 4-1. Material effects sampling stations.

sample. The different fabric panels were measured for light reflectance, before and after ambient exposure, to obtain the total color difference due to fading.[15]

Results of dye-fading for all fabrics at the six Chattanooga area stations are shown in Table 4-3 as annual averages of color measured in National Bureau of Standards (NBS) Units.* Table 4-4 presents information concerning fabrics 4 and 5 by seasons because of the seasonal variation in ozone concentrations.

*A color change of 3 units or less cannot be visually determined.

Table 4-1. METAL CORROSION RATES 1967 AND 1968

(μ/yr)

Station number	Location	Zinc		Steel					
				Annual		3-month			
						1967		1968	
		1967	1968	1967	1968	N[a]	$\bar{X}$[b]	N	$\bar{X}$
107	VAAP-Pond 5	4.3	15.4	63	59	2	73	3	54
108	VAAP-Administration	0.8	1.6	30	-	2	34	4	33
109	VAAP-Harrison School	1.0	4.6	37	35	2	31	4	35
110	VAAP-Rod and Gun	1.1	4.1	27	25	2	22	4	21
140	Federal Building	-	3.4	-	19	2	38	4	24
141	Rossville Health Department	-	2.5	-	24	2	15	4	21
Mean of 6 area stations		1.8	5.2	39	28	12	43	23	31

[a] N = Number of 3-month samples.

[b] $\bar{X}$ = Arithmetic mean rate.

Table 4-2. INTERSTATE SURVEILLANCE PROJECT CUMMULATIVE FREQUENCY DISTRIBUTION OF METAL CORROSION RATES

(μ/yr)

Metal	Year	Exposure, months	Number samples	Occurrence frequency, percentile					
				90	75	50	25	10	1
Zinc	1967	12	124	0.4	0.8	1.4	2.9	4.4	15.2
Steel	1967	12	129	4.0	18.0	31.0	44.0	58.0	76.0
Steel	1967	3	152	4.0	18.0	44.0	67.0	84.0	109.0
Zinc	1968	12	216	0.6	1.0	1.9	3.5	4.9	13.6
Steel	1968	12	204	6.0	16.0	29.0	42.0	53.0	70.0
Steel	1968	3	250	4.0	13.0	38.0	69.0	89.0	132.0

Fabric 1 had marked dye-fading at all six locations, with color changes falling in the National upper quartile. The maximum fading occurred at VAAP-Pond (site #107) where all readings were in the upper 1 percent Nationally.

Fabric 3 dye-fading was excessive, especially at the stations near the ammunition plant. In 1968 all stations near the plant recorded dye-fading in the National upper quartile, as had been expected from the fabric's sensitivity to NO_x.

Fabrics 2, 4, and 5, which represent soiling (2) and ozone sensitivity (4 and 5), did not undergo extreme fading; however, some readings did exceed the ISP 50 percentile level (Table 4-5).

4.3 SILVER TARNISHING

Silver tarnishing results from an interaction between sulfide-type air pollutants and silver. Silver forms sulfide and sulfate in preference to oxide if any sulfur compound is present. The resultant tarnishing effect can be recorded as a decrease in light reflectance from a silver plate and measurements of this property provide a relative index of the presence of sulfide gases in the ambient air.[17]

Table 4-3. MEASURED DYE-FADING RATES 1967 AND 1968
(NBS units)

Station number	Location	Fabric 1				Fabric 2		Fabric 3				Fabric 4		Fabric 5	
		1967		1968		1967		1967		1968		1967		1968	
		N[a]	$\overline{X}$[b]	N	$\overline{X}$	N	$\overline{X}$	N	$\overline{X}$	N	$\overline{X}$	N	$\overline{X}$	N	$\overline{X}$
107	VAAP-Pond 5	3	25	4	27	3	2	3	27	4	36	2	24	4	10
108	VAAP-Administration	3	22	4	25	3	4	3	22	4	32	3	26	4	11
109	VAAP-Harrison School	4	16	4	20	4	1	4	26	4	34	3	19	4	10
110	VAAP-Rod and Gun	4	22	4	23	4	1	4	25	4	33	4	21	3	11
140	Federal Building	2	18	4	19	2	3	2	19	4	27	-	-	4	11
141	Rossville Health Department	2	23	4	20	2	3	2	13	4	22	-	-	4	12

[a] N = Number of samples.
[b] $\overline{X}$ = Arithmetic mean color change rate.

Table 4-4. SEASONAL DYE-FADING RATES
(NBS units)

Station number	Location	Fabric 4: 1967				Fabric 5: 1968			
		Jan. - Mar.	Apr. - June	July - Sept.	Oct. - Dec.	Jan. - Mar.	Apr. - June	July - Sept.	Oct. - Dec.
107	VAAP-Pond 5	-	24	24	-	8	11	12	9
108	VAAP-Administration	-	24	30	22	9	13	14	9
109	VAAP-Harrison School	12	24	22	-	9	12	12	9
110	VAAP-Rod and Gun	11	24	28	21	10	-	14	10
140	Federal Building	-	-	23	-	8	14	13	7
141	Rossville Health Department	-	-	26	-	11	15	14	9

Table 4-5. INTERSTATE SURVEILLANCE PROJECT: FREQUENCY DISTRIBUTION OF DYE-FADING RATES 1967 AND 1968
(NBS units/90 days)

Fabric	Exposure period	1967							1968						
		Number samples	Observation frequency, percentile						Number samples	Observation frequency, percentile					
			90	75	50	25	10	1		90	75	50	25	10	1
1		152	12	14	16	17	19	24	240	17	18	19	21	22	25
2		151	1	2	3	4	6	9	185	6	7	8	10	12	15
3		152	13	16	20	26	33	45	238	17	20	24	31	40	54
4	Jan. to March[a]	103	9	10	12	14	16	22	-	-	-	-	-	-	-
4	April to June	124	14	16	19	22	25	29	-	-	-	-	-	-	-
4	July to Sept.	142	17	20	23	27	30	35	-	-	-	-	-	-	-
4	Oct. to Dec.	145	10	12	14	18	24	30	-	-	-	-	-	-	-
5	Jan. to March[b]	-	-	-	-	-	-	-	180	10	12	13	15	16	19
5	April to June	-	-	-	-	-	-	-	215	9	11	13	15	16	20
5	July to Sept.	-	-	-	-	-	-	-	216	5	6	8	10	12	14
5	Oct. to Dec.	-	-	-	-	-	-	-	237	8	9	11	12	14	16

[a] Fabric 4 used in 1967 but discontinued in 1968.
[b] Fabric 5 first used in 1968.

Clean silver plates were exposed monthly at six locations in the study area and the resultant tarnish, photoelectrically evaluated. Results, expressed as a percent decrease of "luminous apparent reflectance," are shown in Table 4-6.

Table 4-7 contains the ISP frequency distributions for 1967 and 1968. VAAP-Pond 5 (site #107) recorded the highest rate of tarnishing, approaching, but not exceeding, the National upper quartile. In addition, sites #110, #140, and #141 approached the National 50 percentile value in most instances.

4.4 NYLON DETERIORATION

Continuous monofilaments of nylon deteriorate in the presence of corrosive aerosols, especially when stressed or stretched. To simulate this condition,

Table 4-6. AVERAGE YEARLY SILVER TARNISHING RATES 1967 AND 1968
(percentage reflection loss)

Station number	Location	1967		1968	
		N[a]	$\bar{X}$[b]	N	$\bar{X}$
107	VAAP-Pond 5	11	70	12	63
108	VAAP-Administration	11	48	12	42
109	VAAP-Harrison School	11	49	12	44
110	VAAP-Rod and Gun	11	69	12	59
140	Federal Building	7	54	12	68
141	Rossville Health Department	7	52	12	53
Mean of 6 area stations		-	57	-	55

[a] N = Number of monthly samples.
[b] $\bar{X}$ = Yearly average rate.

Table 4-7. INTERSTATE SURVEILLANCE PROJECT: CUMULATIVE FREQUENCY DISTRIBUTION OF AVERAGE YEARLY SILVER TARNISHING RATES, 1967 AND 1968
(percentage reflection loss)

Observation period	Exposure interval, days	Number samples	Occurrence frequency, percentile					
			90	75	50	25	10	1
1967	30	145	31	42	58	71	79	93
1968	30	254	26	38	55	70	81	92

nylon was stretched across a standard polaroid slide mount and exposed to the ambient atmosphere for periods of 30 or 90 days. Effects resulting from air pollution were quantitized by microscopic examination of the physical degradation of the nylon sample.[17]

Table 4-8 shows the annual average of measured nylon deterioration rates at the six Chattanooga area stations, presented as the total number of breaks per exposure time per panel. Cumulative frequency distributions of all ISP stations for 1967 and 1968 are shown in Table 4-9. These tables indicate that the nylon deterioration rates near the ammunition plant were in the top decile, with sites #108 and #109 in the top 1 percent of all National values. By contrast, sites #140 and #141, which reflect conditions in downtown Chattanooga and Rossville, had little or no deterioration.

4.5 RUBBER CRACKING

Rubber cracking is associated with the presence of ozone in the atmosphere and is usually a seasonal phenomena occurring more extensively during the summer months. Stressed rubber strips can be an indicator of the relative impact of ozone pollution in an area.

In the Chattanooga area, weighted rubber strips were exposed to the ambient atmosphere for a period of 1 week and then analyzed microscopically. Cross-section depths of nine consecutive cracks near the center of the strip were measured and the average millimeter depth computed.[18]

Table 4-8. AVERAGE YEARLY NYLON DETERIORATION RATES 1967 AND 1968
(breaks per panel)

Station number	Location	30-day exposure				90-day exposure			
		1967		1968		1967		1968	
		N[a]	$\bar{X}$[b]	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
107	VAAP-Pond 5	10	5.8	12	8.2	4	15.5	4	24.2
108	VAAP-Administration	10	22.7	11	27.6	4	47.0	4	79.0
109	VAAP-Harrison School	10	41.8	12	34.2	3	111.0	4	99.0
110	VAAP-Rod and Gun	10	5.3	12	5.5	3	9.7	4	20.8
140	Federal Building	7	0.3	12	0.0	-	-	4	0.5
141	Rossville Health Department	6	0.2	12	0.0	2	0.0	4	0.0
Mean of 6 area stations		-	15.2	-	18.9	-	45.8	-	44.7

[a] N = Number of samples.
[b] $\bar{X}$ = Average rate.

Table 4-9. INTERSTATE SURVEILLANCE PROJECT CUMULATIVE FREQUENCY DISTRIBUTION OF AVERAGE YEARLY NYLON DISTRIBUTION RATES 1967 AND 1968

(breaks per panel)

Observation period	Exposure interval, days	Number samples	Occurrence frequency, percentile					
			90	75	50	25	10	1
1967	30	145	0	0	0.0	0.2	3.0	18
1967	90	148	0	0	0.0	1.0	8.0	81
1968	30	252	0	0	0.0	0.3	1.4	22
1968	90	253	0	0	0.2	1.4	4.5	55

Annual averages of measured rubber cracking rates for the six stations in the study area are shown in Table 4-10. The cumulative frequency distribution of yearly averages of rubber cracking rates for all ISP stations are shown in Table 4-11. Although there was only moderate cracking in downtown Chattanooga, values reached the top National quartile level near the Volunteer Army Ammunition Plant, sites #108 and #110.

4.6 SUMMARY

Six ISP stations for measuring material effects of air pollution were located in the Chattanooga area during 1967 and 1968. Examination of the data from these stations showed:

1. Steel and zinc corrosion rates at the VAAP-Pond were excessive. Steel corrosion ranked in the upper decile and zinc, the upper one percentile, Nationally. Corrosion rates at the other five study-area sites were not significant.
2. Fabric panels near the Volunteer Army Ammunition Plant showed excessive fading due to nitrogen oxides pollution, with fading values falling in the upper quartile Nationally.
3. Silver tarnishing, the index of sulfide gas pollution, occurred at all locations in the area, but no values exceeded the National ISP upper quartile. Tarnishing values were highest near the ammunition plant.

Table 4-10. AVERAGE YEARLY RUBBER CRACKING RATES AT SELECTED LOCATIONS

(microns/7-day exposure)

Station number	Location	1967		1968	
		N[a]	$\overline{X}$[b]	N	$\overline{X}$
107	VAAP-Pond 5	48	80	52	60
108	VAAP-Administration	49	140	52	90
109	VAAP-Harrison School	49	70	51	70
110	VAAP-Rod and Gun	49	100	50	60
140	Federal Building	31	80	52	80
141	Rossville Health Department	28	60	50	70

[a] N = Number of monthly samples.

[b] $\overline{X}$ = Average rate.

Table 4-11. INTERSTATE SURVEILLANCE PROJECT: CUMULATIVE FREQUENCY DISTRIBUTION OF AVERAGE YEARLY RUBBER CRACKING RATES, 1967 AND 1968

(crack depth in microns)

Observation period	Exposure interval, days	Number samples	Occurrence frequency, by percentile					
			90	75	50	25	10	1
1967	7	140	60	74	96	127	153	256
1968	7	233	41	56	75	100	128	231

4. In the vicinity of the ammunition plant, the gauge of acid aerosol pollution, nylon deterioration, was in the top 10 percent Nationally, with values at the VAAP-Administration and VAAP-Harrison School exceeding the top 1 percentile. Nylon deterioration in downtown Chattanooga and Rossville was not significant.

5. Although elevated values were found near the Volunteer Army Ammunition Plant, in general, the rubber cracking found in the study area was moderate.

5. VEGETATION SURVEYS

A vegetation survey is a convenient way to detect and evaluate an air pollution problem. Studying the tissue of a plant can help identify toxicants and estimate their relative concentration in the atmosphere. In many cases chemical analysis of foliage is also a useful tool.

In 1967,[19] an investigation by NAPCA personnel revealed that vegetation in the vicinity of the Volunteer Army Ammunition Plant had experienced air pollution damage. The injury that developed on vegetation varieties was indicative of exposure to long-term, low concentrations of sulfur dioxide, nitrogen dioxide, or acid mist. This finding initiated a more intensive, selective vegetation study in the Chattanooga - Rossville interstate area from March through May 1968. The investigation was conducted simultaneously with the extensive area-wide air quality study discussed in Chapter 3. During the same time, NAPCA personnel also performed indigenous vegetation surveys near the ammunition plant to further document existing air pollution damage.

The following sections discuss the scope and results of the vegetation surveys.

5.1 INDIGENOUS VEGETATION SURVEYS

Three different indigenous vegetation surveys were made near the Volunteer Army Ammunition plant during 1967 and 1968. These surveys consisted of visual observation of vegetation damage, as well as collection and analysis of vegetation samples.

In 1967, sulfur dioxide, nitrogen dioxide, and acid mist injury was found on the leaves of honeysuckle, rosebush, tulip, and euonymus plants growing north and northeast of the ammunition plant and, also, on pine trees in the central portion of the plant area. The pine needles were found dried or dead, and trunks of the trees were dark in color with no sign of new growth. Pine trees within 1 mile north and northeast of the plant showed acute symptoms such as partial needle death, color fading, and needle tip-burn. Trees within 1 to 2 miles north and northeast of the ammunition plant showed less readily recognized chronic injury, such as the gradual breakdown of chlorophyll. Many tree needles had turned yellow and lost their normal compliment of foliage, causing abnormally low photosynthesis and subsequent growth retardation.

In 1968, nitrogen dioxide and acid mist injury was found on pine, euonymus, dogwood, and honeysuckle grown at the Chattanooga Rod and Gun Club about 3 miles north of the ammunition plant. At the Harrison School, about one-half mile north of the plant, pine needle and honeysuckle leaves were found to have been injured by nitrogen dioxide. At a private residence on Sunny Shore Lane Road, 2 miles north of the plant, damage by nitrogen dioxide and acid mist was found on apple, peach, rosebush, dogwood, honeysuckle, and clematis. Damage by acid mist developed on larkspur, tulip, redbud, and rosebush grown at another private residence, about 1 mile north of the plant.

Table 5-1 indicates the amount and type of injury found at various locations during the 1967 and 1968 surveys.

5.2 SELECTIVE VEGETATION SURVEY

5.2.1 Survey Plan

Vegetation selected for sensitivity to various pollutants was grown in controlled conditions at four locations in the Chattanooga area. Polyethylene greenhouses, 5 ft by 7 ft by 6 ft, were located at the Federal Building (site #5), East Chattanooga (site #9), Rossville (site #7), and the Rod and Gun Club (site #201), from March 29, 1968, though May 28, 1968 (Figure 5-1). Careful control was maintained over each greenhouse with ambient air being the only variable at each location. In addition, a control greenhouse equipped with activated charcoal filtered air was placed at the Rossville site. Greenhouse fans were designed to

Table 5-1. INDIGENOUS VEGETATION INJURY NORTH OF VOLUNTEER ARMY AMMUNITION PLANT

Date	Location	Plant variety	Pollutants	Degree of damage[a]
4/5/67	Central portion of plant manufacturing operation	Pine	SO_2, NO_2, acid mist	1
4/5/67	Gate 20, near Harrison School	Honeysuckle	Acid mist, SO_2	1
4/5/67	Near Waconda Lake	Pine, dogwood	Acid mist, SO_2	3
4/5/67	Private home about 2 miles north of plant	Azalea, dogwood	Acid mist, SO_2	3
		Tulip, rose		3
3/26/68	1/2 mile northeast of plant building 80-4-6	Pine	NO_2	2
		Honeysuckle		3
3/26/68	Rod and Gun Club marina	Pine, euonymus	NO_2, acid mist	3
3/27/68	Near Harrison School 1/2 mile north of plant	Pine, honeysuckle	NO_2	2
3/27/68	Hickory Valley Road, 1 mile south of plant	Euonymus	Acid mist	2
4/9/68	Private home 2 miles north of plant	Apple	NO_2	2
		Peach	NO_2	2
		Rosebush	NO_2	1
		Dogwood	NO_2	1
		Honeysuckle	Acid mist	4
		Clematis	Acid mist	4
4/9/68	Private home 1 mile north of plant	Poppy	Acid mist	3
		Larkspur	Acid mist	3
		Snowball bush	Acid mist	3
		Tulip	Acid mist	3
		Redbud	Acid mist	3
		Redbush	Acid mist	3
4/9/68	Rod and Gun Club	Dogwood	NO_2	1
		Honeysuckle	NO_2	1

[a] Scale: 1, severe; 2, moderate; 3, mild; 4, little.

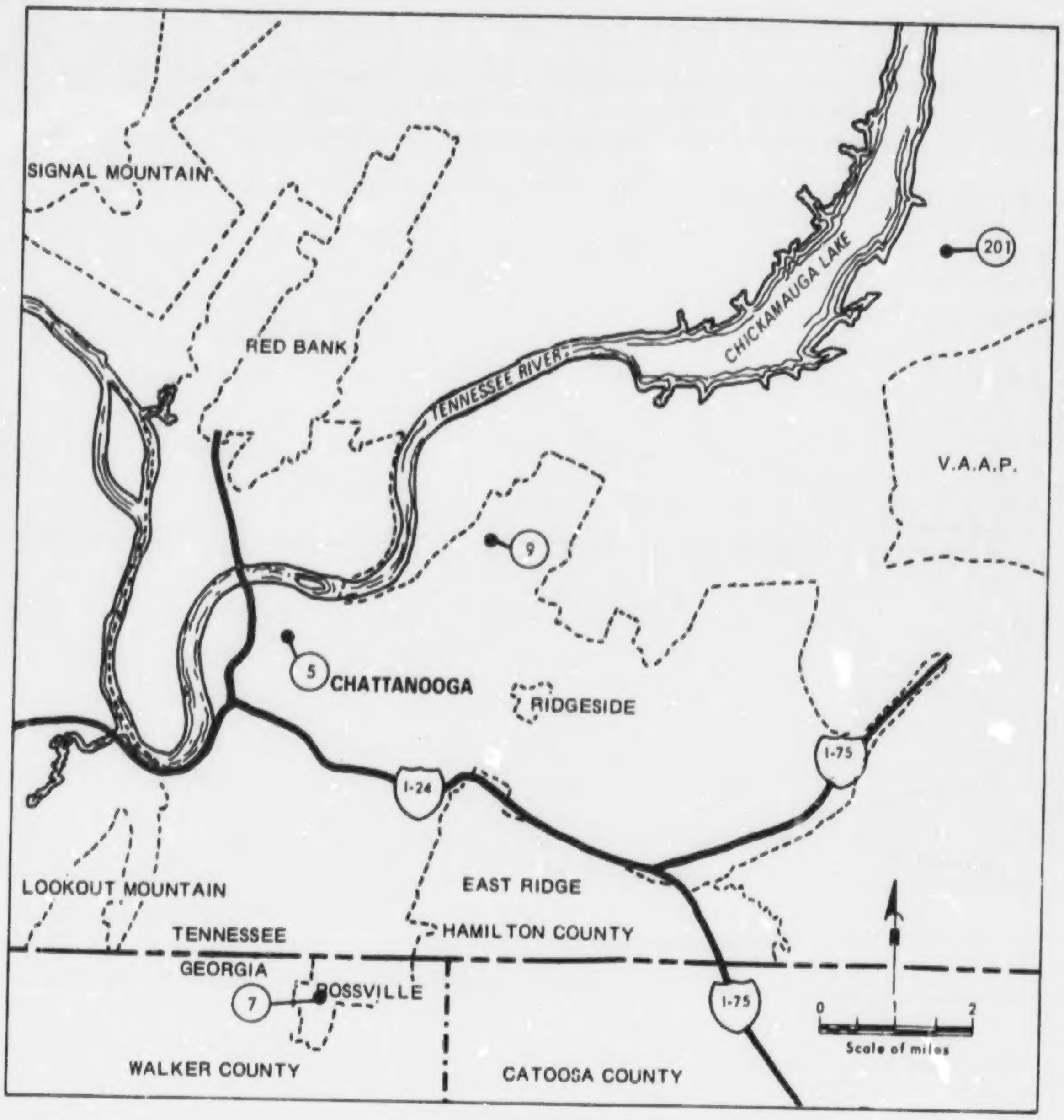

SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
201
V.A.A.P.
9
5
CHATTANOOGA
RIDGESIDE
I-24
I-75
LOOKOUT MOUNTAIN
EAST RIDGE
TENNESSEE
HAMILTON COUNTY
GEORGIA
7
ROSSVILLE
I-75
0
2
Scale of miles
WALKER COUNTY
CATOOSA COUNTY

Figure 5-1. Vegetation shelter sites.

circulate ambient air through each chamber at the rate of one air volume change per minute.

Four gladioli plants; three tobacco; two each of petunia, geranium, and begonia; and one tomato plant were placed in each greenhouse. In addition, two pinto beans were planted at weekly intervals in each location. The plants were grown hydroponically in a vermiculite support medium containing a complete nutrient solution. Plant pots were placed in shallow trays to which nutrient solution was added weekly. Each week the vermiculite was flushed with deionized water, and the trays cleaned and refilled with nutrient solution.

Vegetation was examined for leaf injury on Monday, Wednesday, and Friday of each week. Accumulation of leaf injury and suppression of plant growth were summarized after 30 days and at the end of the 60-day study period.

Nitrogen dioxide and sulfur dioxide instrumentation was located adjacent to each of the four greenhouse sites. An instrument was placed inside each greenhouse to record oxidant values. Sampling results are presented in Figure 5-2.

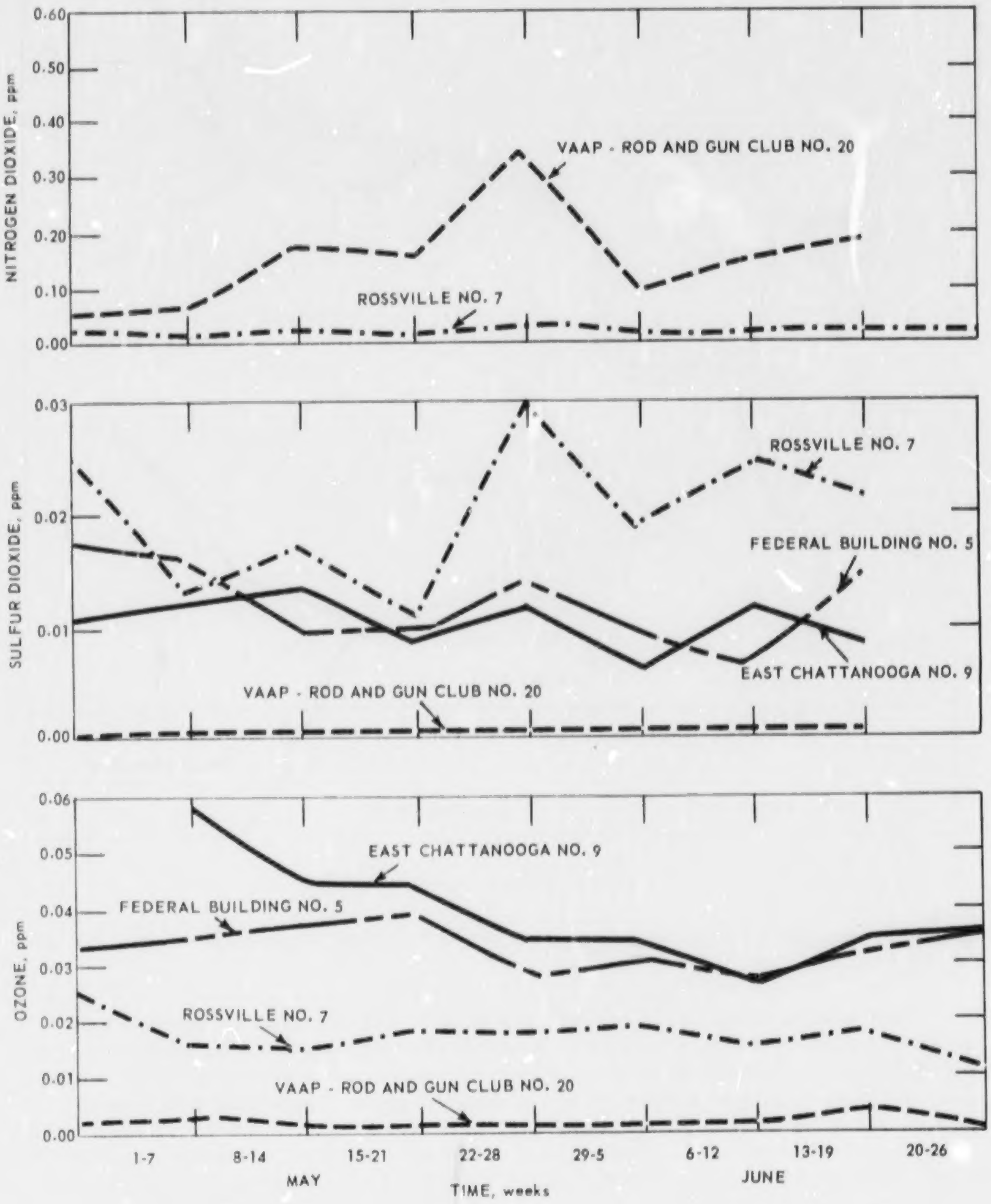


Figure 5-2. Weekly average daytime pollutant levels experienced at vegetation sites.

Oxidant values are reported for time periods between 1000 and 1600, and sulfur dioxide and nitrogen dioxide values for periods between 0600 and 1600. These periods were chosen because plants are most physiologically active, thus most susceptible to injury during those times of day.

5.2.2 Specific Damage

The vegetation study was broken down into two periods: March 27 to April 24, 1968, and April 25 to May 28, 1968. Table 5-2 shows the type and extent of damage found at each location during each period of study. Specific injury is listed according to pollutant. Non-specific injury is listed according to damage, such as growth suppression.

The damage that developed on plant varieties exposed in the Chattanooga study area was attributed to nitrogen dioxide, ozone, peroxyacyl nitrate (PAN), sulfur dioxide, hydrogen fluoride, and interaction of low concentrations of these and other pollutants. No damage developed on the plants grown in the control greenhouse located at Rossville.

The most important damage to experimental vegetation was probably that recorded at the Rod and Gun Club site. Vegetation there was frequently exposed to extremely high concentrations of nitrogen dioxide and acid mist. Tomato damage was observed on several occasions, especially after instances of

Table 5-2. INDIGENOUS VEGETATION DAMAGE

Vegetation	Pollutant and damage[a], by locale			
	Rossville	Federal Building	East Chattanooga	Rod and Gun Club
FIRST STUDY PERIOD, 3/27/68 through 4/24/68				
Tobacco	O_3 (E)	O_3 (S)	O_3 (S)	NO_2 (M)
Pinto bean	O_3 (T)	O_3, PAN (M)	O_3, PAN (M)	NO_2 (T)
Petunia	GS (M)	GS (M)	GS (M)	NO_2 (T)
Begonia	O_3, GS (T)	O_3, GS (M)	O_3, GS (M)	NO_2 (T)
Geranium	–	–	–	NO_2 (T)
Tomato	–	–	–	NO_2 (M)
SECOND STUDY PERIOD, 4/25/68 through 5/28/68				
Tobacco	O_3, SO_2, NO_2 (E)	O_3 (M)	O_3 (M)	NO_2 (E)
Pinto bean	O_3, SO_2, NO_2	GS (M)	GS (M)	NO_2 (M)
Petunia	O_3, SO_2, NO_2 (M)	GS (M)	GS (M)	NO_2 (M)
Begonia	GS (M)	O_3 (T)	O_3 (T)	NO_2 (M)
Geranium	GS (M)	GS (M)	GS (M)	NO_2, GS (M)
Tomato	–	–	–	NO_2 (E)

[a]GS - growth suppression.
PAN - peroxyacyl nitrate.
T - trace, 0 to 5 percent leaf damage.
M - moderate, 5 to 25 percent leaf damage.
E - extensive, 25 to 50 percent leaf damage.
S - severe, >50 percent leaf damage.

high nitrogen dioxide pollution. Maximum leaf damage was recorded on April 30, 1968, coinciding with an hourly nitrogen dioxide concentration of approximately 2.9 ppm. This concentration is the same magnitude as that reported to cause visible tomato leaf damage.[20]

These same tomato plants experienced from 5 to 25 percent leaf damage during the first 5-week study period, and from 25 to 50 percent leaf damage during the second period. The leaves on the plant tended to curl and had a noticeably darker green color. Such a change in appearance is similar to the nitrogen dioxide damage found by Taylor[21] at Riverside, California.

In addition to nitrogen dioxide damage, ozone and PAN damage was found in the area-wide studies. Plants exposed at the Rossville, Federal Building, and East Chattanooga sites developed characteristic ozone damage, while PAN injury developed on pinto bean plants at the Federal Building and East Chattanooga (Table 5-2). Ozone and PAN symptoms found at these sites were indistinguishable from symptoms developed on comparable plants exposed to irradiated automobile exhaust fumes in studies at the R. A. Taft Sanitary Engineering Center in Cincinnati, Ohio.[22]

Tobacco (W_3 variety) exposed to ambient air at Rossville developed extensive leaf damage even though neither oxidant, sulfur dioxide, nor nitrogen dioxide concentration was high enough to cause the damage, individually. Preliminary experiments[23] with these pollutants suggest that a mixture containing 0.05 ppm of each may injure tobacco (W_3 variety). Damage at the Rossville site can apparently be attributed to the synergistic action of low concentrations of pollutants.

Fluorides are cumulative vegetation toxicants, usually associated with long-term buildup in the leaves of plants. When absorbed by the leaves, fluorides are readily translated to the margins and tips where they concentrate and accumulate. Accumulation of both gaseous and particulate fluorides results in the phenomenon known as "tip-burn." At lower concentrations, fluorides reduce plant growth and cause lower yields. Hydrogen fluoride, for example, has been found to be toxic to some plants in exposures as low as 0.1 part per billion (ppb) for 5 weeks.[25]

After 5 weeks of exposure to ambient air at the four locations, tip and margin burn developed only at the Federal Building site. Gladiolus leaf samples from all sites were analyzed for fluoride accumulation. A maximum leaf fluoride concentration of 50 μg/g was measured in samples from the Federal Building (Table 5-3).

TABLE 5-3. FLUORIDE ACCUMULATION IN GLADIOLUS LEAF TISSUE FROM MARCH 27, 1968, THROUGH MAY 28, 1968

Station	Fluoride, μg/g	
	0 - 2 in. from tip	2 - 4 in. from tip
Rossville	35	<25
Federal Building	50	<25
East Chattanooga	25	25
Rod and Gun Club	25	<25
Control	<25	<25

On May 28, 1968, an indigenous vegetation survey was made in the vicinity of several potential fluoride sources. Results from this survey, shown in Table 5-4, indicate considerable fluoride accumulation at two locations in the study area. These findings were limited to a small locale, however, and do not indicate an area-wide problem.

Table 5-4. FLUORIDE ACCUMULATION IN LEAF TISSUE: INDIGENOUS VEGETATION SURVEY MAY 28, 1968

Location	Tree type	Portion of leaf	Fluoride, µg/g
12th Street, 1 block East of Hickory Street,	Maple	Entire Margin	<25 <25
2 miles northeast of brick plant	Maple	Margin Base	150 150
South Highland Park Street adjacent to manufacturing facility	Maple	Entire	235
Southwest of Federal Building	Crab apple	Entire	<25

5.2.3 Non-Specific Damage

Air pollutants often produce vegetation damage that is not readily apparent to the normal observer. Growth may be suppressed or inhibited and other physical characteristics such as color affected.^{24} Table 5-5 and 5-6 show the non-specific air pollution effects observed on the vegetation grown at four study-area sites. Table 5-5 lists the percentage reduction in growth of exposed specimens compared to control specimens of the same age. A suppression value of 25 percent means that the plant grown in an experimental greenhouse site was estimated, by visual comparison, to be 25 percent smaller than a similar plant grown in the Rossville control greenhouse.

Results show that plants at the Rod and Gun Club site experienced more overall growth suppression than those at the other three sites (Table 5-3). Four plants - tobacco, petunia, begonia, and tomato, experienced or equaled the highest growth suppression for the study. Suppression was marked in the tobacco plant (45 percent) and the tomato plant (35 percent). Plants at the Rossville site also experienced a high degree of growth suppression, especially the geranium (35 percent) and tobacco plant (35 percent).

Table 5-5. GROWTH SUPPRESSION OF SELECTIVE VEGETATION (percent < control)

	Location			
Vegetation	Rossville	Federal Building	East Chattanooga	Rod and Gun Club
Tobacco	35	30	30	45
Pinto bean	25	20	20	15
Petunia	25	20	20	25
Begonia	10	15	15	20
Geranium	35	20	20	25
Tomato	10	0	0	35

Table 5-6. COMPARISON OF EXPOSED AND CONTROL TOBACCO PLANTS GROWN MARCH 27, THROUGH MAY 28, 1968

Parameter	Location				
	Rossville	Federal Building	East Chattanooga	Rod and Gun Club	Control
Diameter of stem, in.	0.85	1.00	1.00	0.80	1.10
Stem cross section area, in^2	0.57	0.78	0.78	0.50	0.95
Cross section area, % <control	40	18	18	47	0
Root systems weight, gm	778	905	905	593	925
Root system weight, % <control	16	2	2	36	

For comparative purposes, Table 5-6 presents measurements of tobacco plants grown at the four study locations during a 60-day period. Information presented in the table indicates that the physical properties of the tobacco plants grown at the Rod and Gun Club were adversely affected by air pollutants. These plants had smaller stem diameters, smaller cross-sectional areas, and smaller root systems than plants grown at the other three sites.

5.3 SUMMARY AND CONCLUSIONS

During 1967 and 1968, indigenous vegetation surveys conducted in the vicinity of the Volunteer Army Ammunition Plant revealed damage characteristic of overexposure to nitrogen dioxide, sulfur dioxide, and acid mist. Injury was observed on honeysuckle, rosebush, tulip, and euonymus. Pine trees growing adjacent to the plant were also severely damaged, many showing dried or dead needles and discolored trunks. Nitrogen dioxide and acid-mist injury were found on pine needles, euonymus, dogwood, and honeysuckle at the Chattanooga Rod and Gun Club, 3 miles from the plant.

At the four study sites where selected vegetation was exposed, damage attributed to nitrogen dioxide, ozone, PAN, sulfur dioxide, hydrogen fluoride, and an interaction of low concentrations of these and other pollutants developed. The most dramatic damage was documented at the Rod and Gun Club site where extensive darkening and curling of tomato leaves was found. At this same site, petunia, begonia, tobacco, and tomato plants experienced maximum growth suppression.

6. EMISSIONS INVENTORY

In order to determine the sources, types, and quantities of potential pollutants emitted in Hamilton County, Tennessee, and Walker and Catoosa Counties, Georgia; the Chattanooga Bureau of Air Pollution Control and NAPCA conducted a comprehensive emission inventory for the three-county area in 1969. Questionnaires were sent to 219 industrial and commercial establishments requesting 1968 pollutant inventories of: particulate matter, sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and acid mist.

Air pollution emission sources were divided into four categories: (1) Stationary Fuel Combustion, (2) Solid Waste Disposal, (3) Mobile Sources, and (4) Industrial Process Losses. Each of these classifications was subdivided into two groups, point sources and area sources. Facilities emitting large quantities of pollutants were considered individually as point sources, while commercial and residential fuel users, motor vehicles, small industries, and on-site refuse incinerators were considered area sources.

Emissions were estimated from information such as fuel consumption, production quantities, solid waste quantities, vehicle-miles, and existing control equipment and efficiencies. A detailed discussion of inventory techniques used to estimate emissions is contained in Appendix D.

The Universal Transverse Mecator System (UTM) was used as the reference system for grid delineation of the study area. One-, five-, and ten-kilometer grids were used, covering an area of 3100 km^2 (1196 square miles). The City of Chattanooga was divided into fifty 1-kilometer grids, and the remainder of the area divided into 41 larger sized grids (Figures 6-1 and 6-2).

6.1 EMISSION SOURCE CATEGORIES

Table 6-1 shows the results of the emission survey. Quantities of particulate matter, sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and acid mist are presented for each of the four major source categories. A more detailed breakdown of Stationary Fuel Combustion, Mobile Sources, and Solid Waste Disposal is given in Appendix D. The following paragraphs reflect the survey results by category and by pollutant.

6.1.1 Stationary Fuel Combustion Sources

Coal, fuel oil, and natural gas are the only significant heating fuels used in the three-county area. The burning of coal and fuel oil generates appreciably more air pollutants than does natural gas. Particulate matter and sulfur oxides are released in large quantities from the combustion of coal and fuel oil, whereas the principal contaminants from natural gas combustion are oxides of nitrogen.

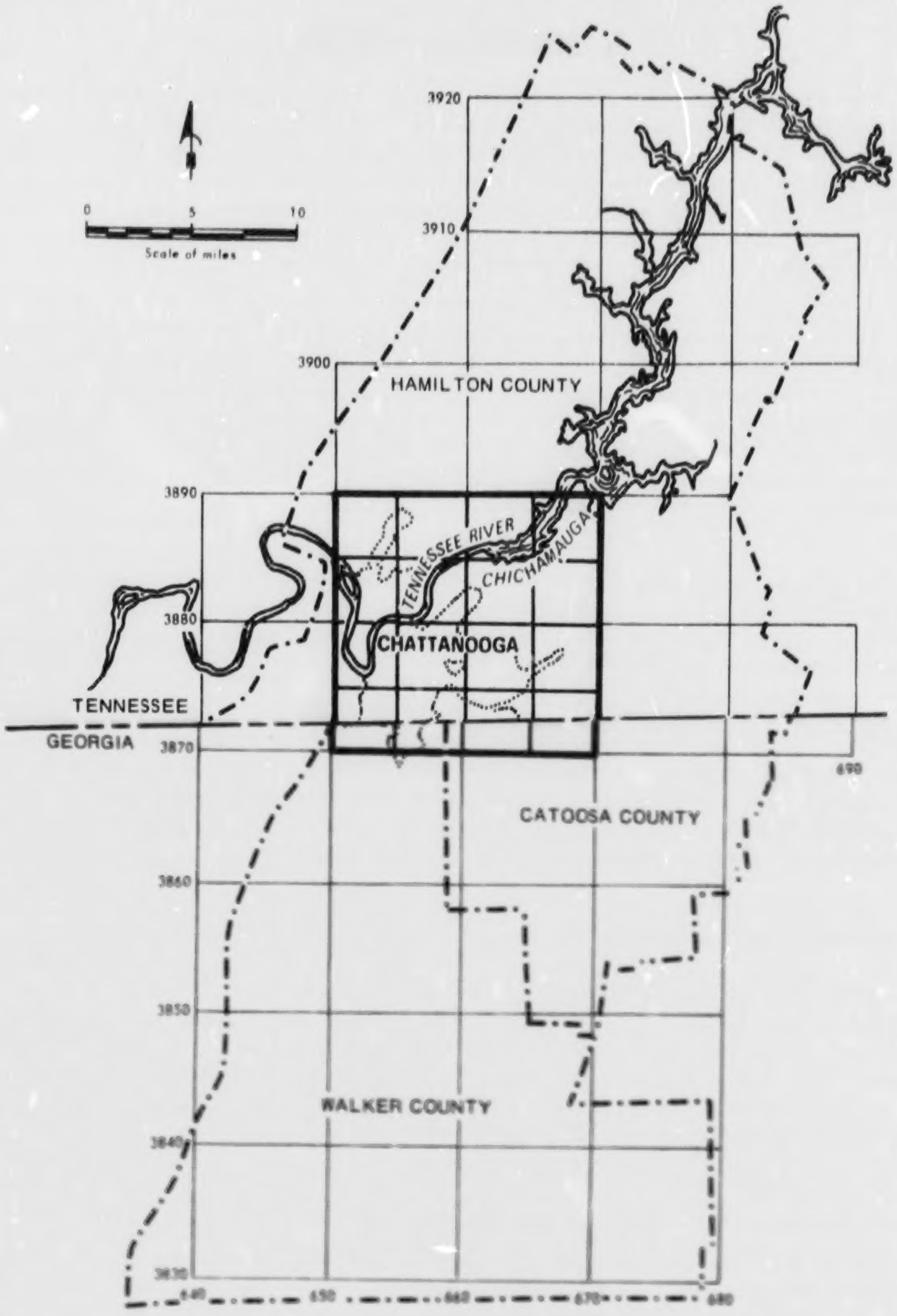

0
5
10
Scale of miles
3920
3910
3900
HAMILTON COUNTY
3890
TENNESSEE RIVER
CHICHAMAUGA
3880
CHATTANOOGA
TENNESSEE
GEORGIA
3870
690
CATOOSA COUNTY
3860
3850
WALKER COUNTY
3840
3830
640
650
660
670
680

Figure 6-1. Study area grid coordinate system.

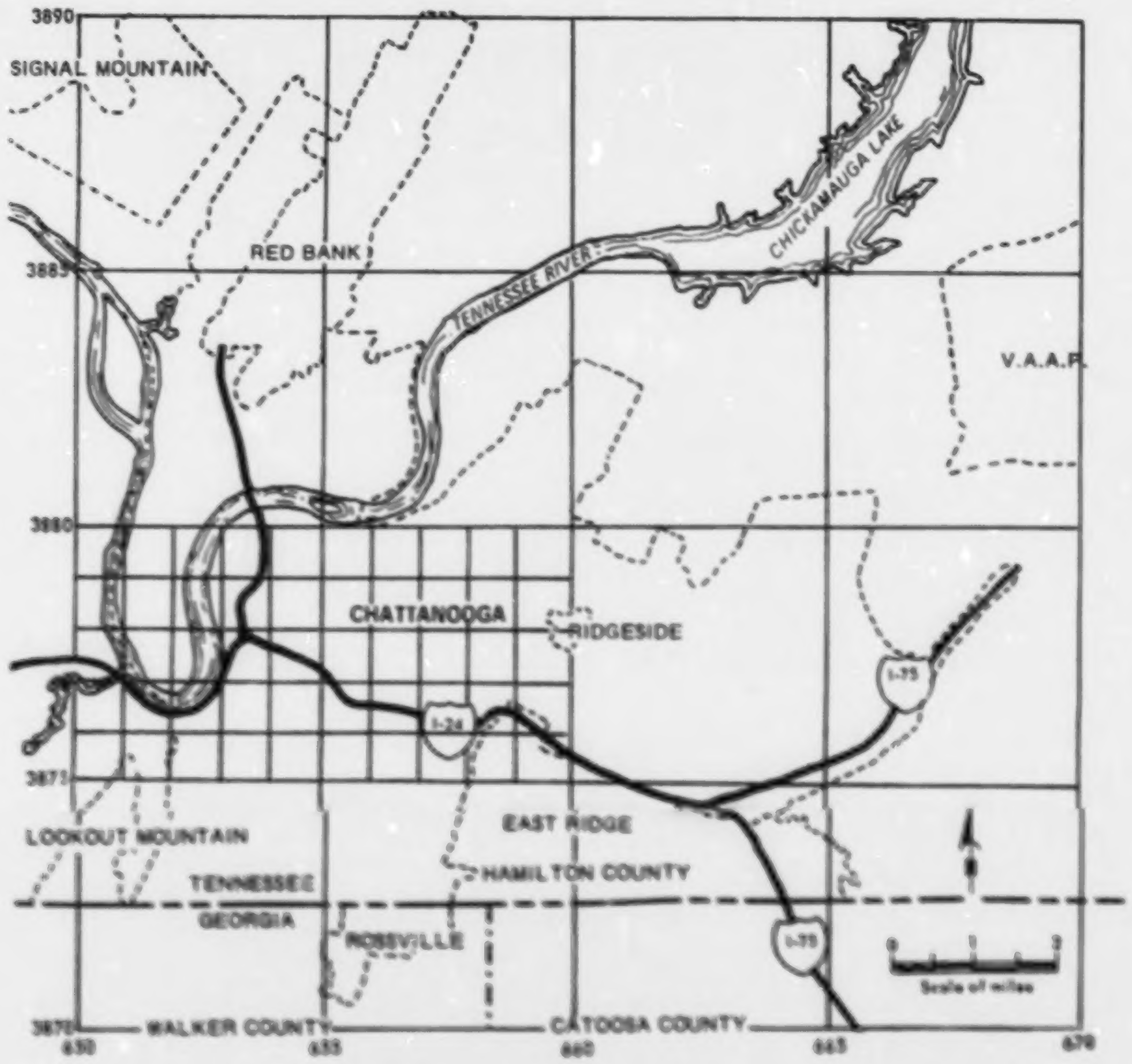

3890
SIGNAL MOUNTAIN
RED BANK
3885
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
3880
CHATTANOOGA
RIDGESIDE
I-75
I-24
3875
LOOKOUT MOUNTAIN
EAST RIDGE
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
I-75
0
1
2
Scale of miles
3870
WALKER COUNTY
CATOOSA COUNTY
650
655
660
665
670

Figure 6-2. Detail of 1-kilometer grids for downtown area.

6.1.1.1 Residential fuel combustion

Residential fuel combustion includes a class of ground-level, widespread sources of air pollution. Emissions from these sources are related to the climatology of an area and are maximum during the colder seasons of the year. In Chattanooga, emissions from residential fuel combustion were the source of approximately 3 percent of the particulate, 10 percent of the sulfur oxides, and 1 percent or less of the nitrogen oxides, carbon monoxide, and hydrocarbon emissions. Combustion of coal in residences accounted for 9 percent of the total area sulfur oxides emissions, and only 2 percent of the total particulate emissions.

6.1.1.2 Commercial and governmental fuel combustion

Commercial and governmental fuel combustion generally refers to fuel used for space and water heating for all non-industrial, non-residential buildings. In the Chattanooga area this classification contributed only 2 percent to the particulate emissions, 5 percent to the sulfur oxides emissions, and less than 1 percent to the nitrogen oxides, carbon monoxide, and hydrocarbons.

Table 6-1. SUMMARY OF 1968 AIR POLLUTANT EMISSIONS IN CHATTANOOGA METROPOLITAN AREA[a]

(tons/yr)

Pollutants	Stationary fuel combustion				Mobile sources					Solid waste disposal				Industrial process losses				County totals
	Industrial	Commercial and government	Residential	Total	Vehicle		Aircraft	Railroads	Total	Private incinerators	Burning dumps	Back yard burning	Total	Industrial	Gas handling and storage	Solvent losses	Total	
					Gasoline	Diesel												
Hamilton Co.																		
Particulates	3,003	233	218	3,454	690	153	34	94	1,061	55	905	320	1,280	4,962	-	-	4,962	10,697
SO_x	4,970	448	654	6,072	510	47	-	35	630	12	24	20	56	2,053	-	-	2,053	8,801
NO_x	3,541	162	283	3,986	6,497	336	142	100	7,103	21	210	175	406	18,243	-	-	18,243	29,794
HC	77	78	197	352	14,671	227	504	117	15,463	34	1,540	2,313	3,887	0	3,708	2,149	5,857	25,565
CO	249	393	962	1,505	135,057	100	2,454	51	138,247	229	1,640	951	2,820	54,766	-	-	54,766	187,423
Acid mist														8,868	-	-	8,868	8,868
Walker Co.																		
Particulates	36	10	70	116	98	2	-	-	100	-	84	160	244	37	-	-	37	497
SO_x	61	21	238	320	74	1	-	-	75	-	2	10	12	-	-	-	-	407
NO_x	79	8	64	151	907	6	-	-	913	-	20	90	110	-	-	-	-	1,192
HC	-	6	66	70	2,884	2	-	-	2,886	-	140	1,190	1,330	-	1,072	434	1,506	4,992
CO	1	10	219	230	17,917	1	-	-	17,918	-	150	490	640	-	-	-	-	18,896
Catoosa Co.																		
Particulates	10	3	9	22	25	10	-	-	35	-	-	80	80	-	-	-	-	165
SO_x	20	6	27	53	19	6	-	-	25	-	-	5	5	-	-	-	-	93
NO_x	21	2	7	30	307	31	-	-	338	-	-	44	44	-	-	-	-	472
HC	-	1	6	9	826	19	-	-	845	-	-	162	162	-	99	202	301	1,737
CO	1	5	39	45	7,101	9	-	-	7,110	-	-	240	240	-	-	-	-	7,395
Study total																		
Particulates	3,077	238	297	3,600	827	201	34	94	1,156	55	989	560	1,604	4,999	-	-	4,999	11,359
SO_x	5,071	475	899	6,445	603	74	-	35	700	12	26	35	73	2,053	-	-	2,053	9,301
NO_x	3,641	172	914	4,127	7,701	405	142	100	8,348	21	230	309	560	18,243	-	-	18,243	31,458
HC	77	90	271	421	17,591	248	504	117	18,460	34	1,680	4,085	5,799	0	4,879	2,785	7,664	32,294
CO	252	410	1,329	1,979	150,655	110	2,454	51	158,270	229	1,790	1,681	3,700	54,766	-	-	54,766	213,714
Acid mist	-	-	-	-	-	-	-	-	-	-	-	-	-	8,868	-	-	8,868	8,868

[a] SO_x calculated as SO_2, NO_x calculated as NO_2, HC calculated as methane.

6.1.1.3 Industrial fuel combustion

Industrial fuel combustion from space heating, process heating, and steam power generation is an important source of air pollution in the Chattanooga area. Approximately 27 percent of the particulate, 55 percent of the sulfur oxides, and 12 percent of the nitrogen oxides emissions are discharged as a result of industrial fuel combustion.

6.1.2 Mobile Sources

Gasoline- and diesel-fueled motor vehicles, diesel railroad engines, and aircraft are included in Mobile Sources. Altogether, they are responsible for the release of approximately 10 percent of the particulate, 8 percent of the sulfur oxides, 27 percent of the nitrogen oxides, 57 percent of the hydrocarbons, and 72 percent of the carbon monoxide emissions (Table 6-1, Appendix D). The gasoline-fueled automobile is the major source of the area's hydrocarbon and carbon monoxide pollutants, emitting 17,500 and 150,700 tons per year, respectively.

6.1.3 Solid Waste Disposal

The Solid Waste Disposal Category covers incineration of refuse, rubbish, and other solid waste materials at burning dumps, incinerators, and on-site waste piles. Open burning and backyard burning are the largest contributors, adding 13 percent to the total area particulate emissions, and 18 percent to the area hydrocarbon emissions. The contributions of sulfur oxides, nitrogen oxides, and carbon monoxide from solid waste disposal are negligible.

6.1.4 Industrial Process Losses

This category is concerned with all air pollution emitted from industrial sources other than fuel combustion and solid waste disposal. The emissions from fuel used for industrial process heating are included in the Stationary Fuel Combustion category.

Industrial Process Losses include losses from industrial manufacturing, gasoline handling and storage, and solvent evaporation. Gasoline handling and storage, and solvent losses are only important when considering hydrocarbon emissions. They amounted to approximately 15 percent and 9 percent, respectively. Industrial manufacturing losses account for 44 percent of the particulate, 26 percent of the carbon monoxide, 58 percent of the nitrogen oxides, 22 percent of the sulfur oxides, and 100 percent of the acid mist emissions in the area.

Table 6-2 delineates emissions from industrial manufacturing and reflects the relative importance of each. None of the sources listed in the table are in Georgia.

6.2 POLLUTANTS

6.2.1 Particulate Matter

An estimated 11,400 tons of particulate matter was released in the metropolitan Chattanooga interstate area during 1968. As shown in Figure 6-3, the major sources of these emissions, Industrial Process Losses and Stationary

Table 6-2. INDUSTRIAL MANUFACTURING LOSSES, 1968
(tons/year)

Location	Pollutant					
	Particulate	SO_x	NO_x	HC	CO	Acid mist
Hamilton County	4.962	2.053	18.243	-[a]	54.766	8.868
Foundries	3.084	1.221	-	-	54.766	-
Coking Operations	200	-	-	-	-	-
Quarry operations	144	-	-	-	-	-
Cement production and concrete products	943	-	-	-	-	-
Grain mills	441	-	-	-	-	-
Chemical plants	150	832	18.243	-	-	8.868
Walker County	37	-	-	-	-	-
Quarry operations	37					
Catoosa County	-	-	-	-	-	-
Area total	4,999	2.053	18.243	-	54.766	8.868

[a] Negligible values indicated by dash (–).

Fuel Combustion, contribute approximately 44 and 32 percent of this total, respectively. The remaining particulate emissions come from Mobile Sources (10 percent) and Solid Waste Disposal (14 percent). Less than 6 percent of the study area particulate emissions were discharged from sources in the two counties of Georgia.

The foundry industry in Hamilton County, Tennessee is the largest emitter of particulate matter; releasing 3100 tons through process losses, approximately 27 percent of the total study-area emissions. The production of cement, cement products, and asphaltic concrete products accounts for about 940 tons per year, or approximately 8 percent of the total. Grain milling processes release about 440 tons per year or about 4 percent.

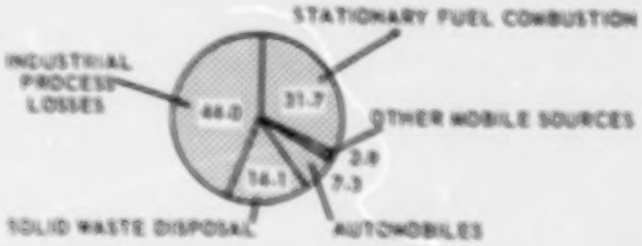


Figure 6-3. Percentage contribution of particulate by source category.

Particulate emissions ($tons/km^2$-yr) by grid are shown in Figures 6-4 and 6-5. These figures show the area of maximum emissions to be centered in the Chattanooga Valley, west of Missionary Ridge.

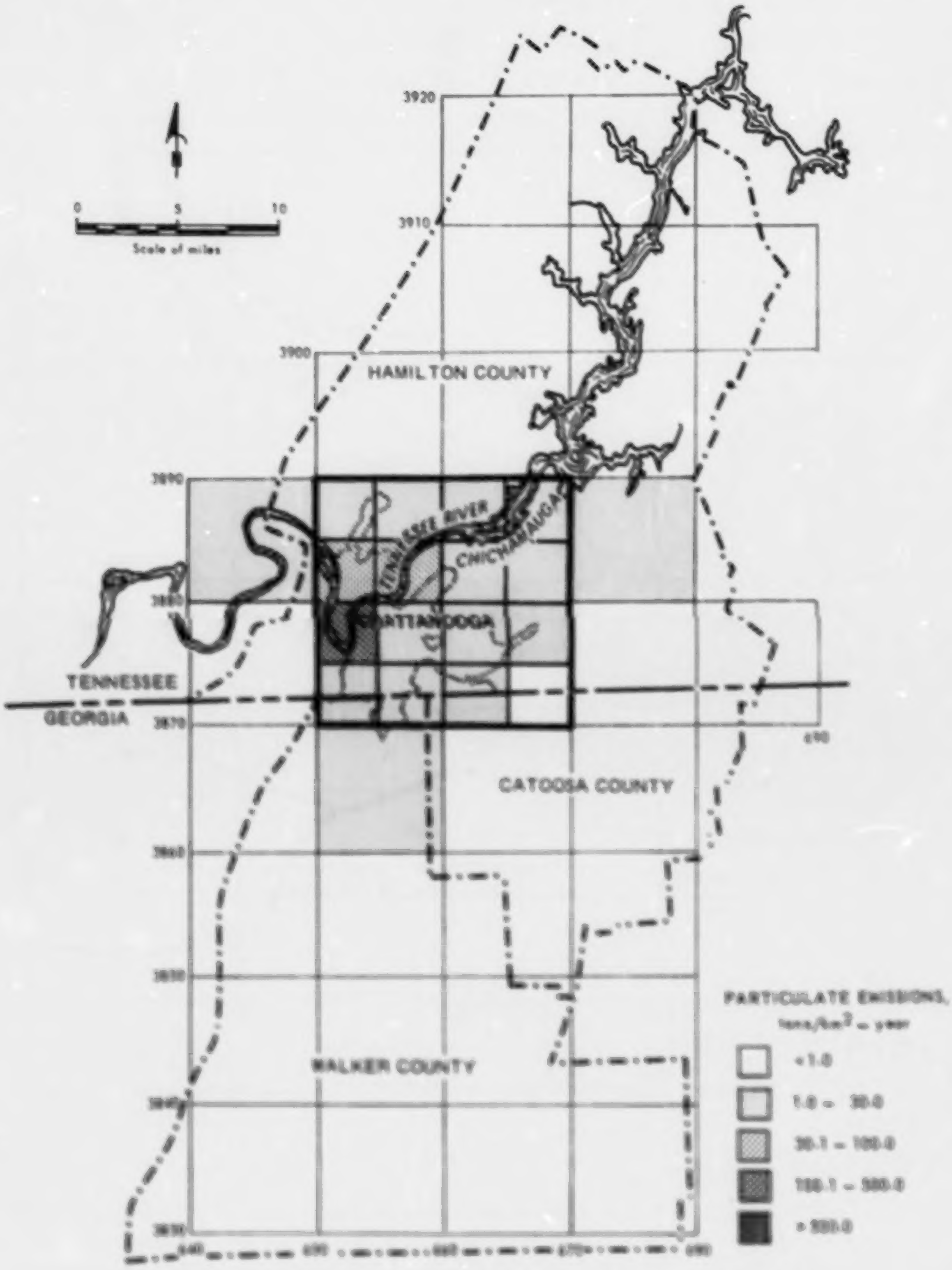

0
5
10
Scale of miles
3920
3910
3900
HAMILTON COUNTY
3890
TENNESSEE RIVER
CHICKAMAUGA
3880
CHATTANOOGA
TENNESSEE
GEORGIA
3870
690
CATOOSA COUNTY
3860
3850
WALKER COUNTY
3840
3830
640
650
660
670
680
PARTICULATE EMISSIONS,
tons/km² – year
□ <1.0
□ 1.0 – 30.0
▨ 30.1 – 100.0
▩ 100.1 – 500.0
■ > 500.0

Figure 5-4. Particulate emission density - 1985.

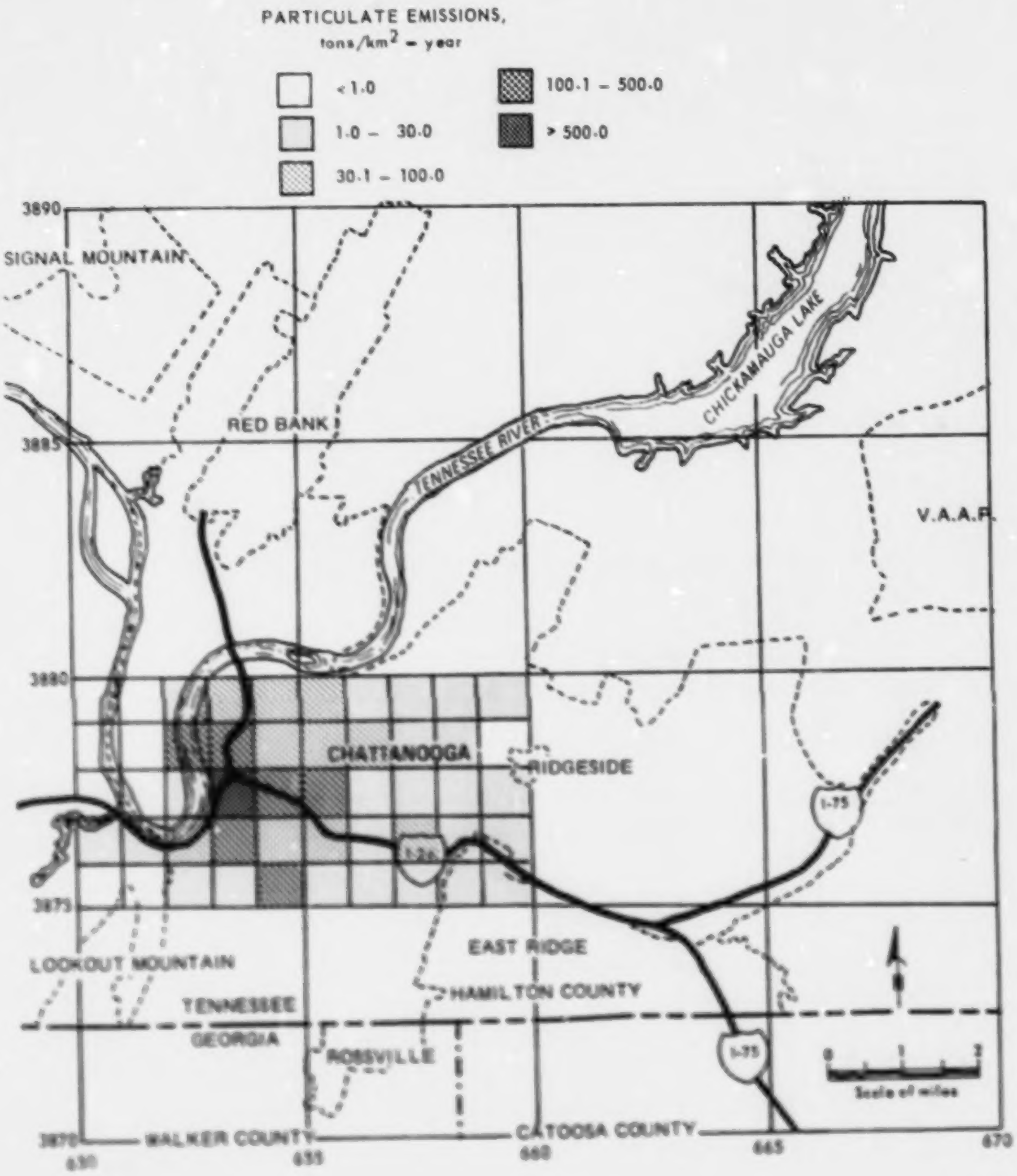

PARTICULATE EMISSIONS,
tons/km² – year
< 1.0
1.0 – 30.0
30.1 – 100.0
100.1 – 500.0
> 500.0
3890
3885
3880
3875
3870
SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
CHATTANOOGA
RIDGESIDE
I-24
I-75
EAST RIDGE
LOOKOUT MOUNTAIN
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
WALKER COUNTY
CATOOSA COUNTY
0
1
2
Scale of miles
650
655
660
665
670

Figure 6-5. Particulate emission density for 1-kilometer grids only.

6.2.2 Nitrogen Oxides

An estimated 31,500 tons of nitrogen oxides was released in the metropolitan Chattanooga area in 1968. The two largest nitrogen oxides sources were gasoline-fueled automobiles (25 percent) and Industrial Process Losses (58 percent). The remaining nitrogen oxides came from Stationary Fuel Combustion (13 percent), Mobile Sources other than automobiles (2 percent), and the combustion of solid wastes (2 percent). Less than 6 percent of the total nitrogen oxides emissions came from sources in Georgia.

The release of approximately 18,200 tons of nitrogen oxides from Industrial Processes was attributed to the production of nitric acid and TNT in the area east of Missionary Ridge. The release of this large quantity of nitrogen oxides in an area with the stable meteorological characteristics discussed in Chapter 2, substantiates the high measured concentrations presented in Chapter 3.

Figure 6-6 illustrates the contribution of each significant source of nitrogen oxides. Figures 6-7 and 6-8 show the density of annual emissions.

6.2.3 Sulfur Oxides

An estimated 9300 tons of sulfur oxides was emitted in the study area during 1968. The three major sources were Stationary Fuel Combustion (69 percent), Industrial Process Losses (22 percent), and Mobile Sources (8 percent). The majority of the 6400 tons of sulfur oxides derived from fuel combustion, was from industrial fuel combustion with only 900 tons from residential combustion. Only 5 percent of the total area sulfur oxides were discharged by sources in Georgia. The remaining 95 percent were released from sources in Hamilton County, Tennessee.

Of the sulfur oxides emitted by fuel combustion, 90 percent came from burning coal, 6 percent came from burning fuel oil, and the remaining 4 percent came from the combustion of industrial process gases (by-products) Figure 6-9 illustrates the percent contribution of each source to the total area sulfur oxides emission. Figures 6-10 and 6-11 show the emission density by grids.

6.2.4 Carbon Monoxide

An estimated 213,700 tons of carbon monoxide was emitted in the metropolitan Chattanooga interstate area during 1968. The major source of these emissions was gasoline-fueled automobiles, which released approximately 150,700 tons or 71 percent of the area total. Industrial Process Losses, chiefly attributed to uncontrolled foundry cupolas, were responsible for 26 percent of the total. The remaining carbon monoxide emissions were from Solid Waste Disposal (2 percent), other Mobile Sources (1 percent), and Stationary Fuel Combustion (<1 percent). Twelve percent of the total emissions were discharged by sources in Georgia.

Figure 6-12 illustrates the source of carbon monoxide in the study area. Figures 6-13 and 6-14 show the emission density by grids.

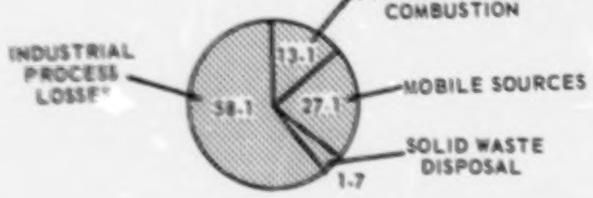


Figure 6-6. Percentage contribution of nitrogen oxides by source category.

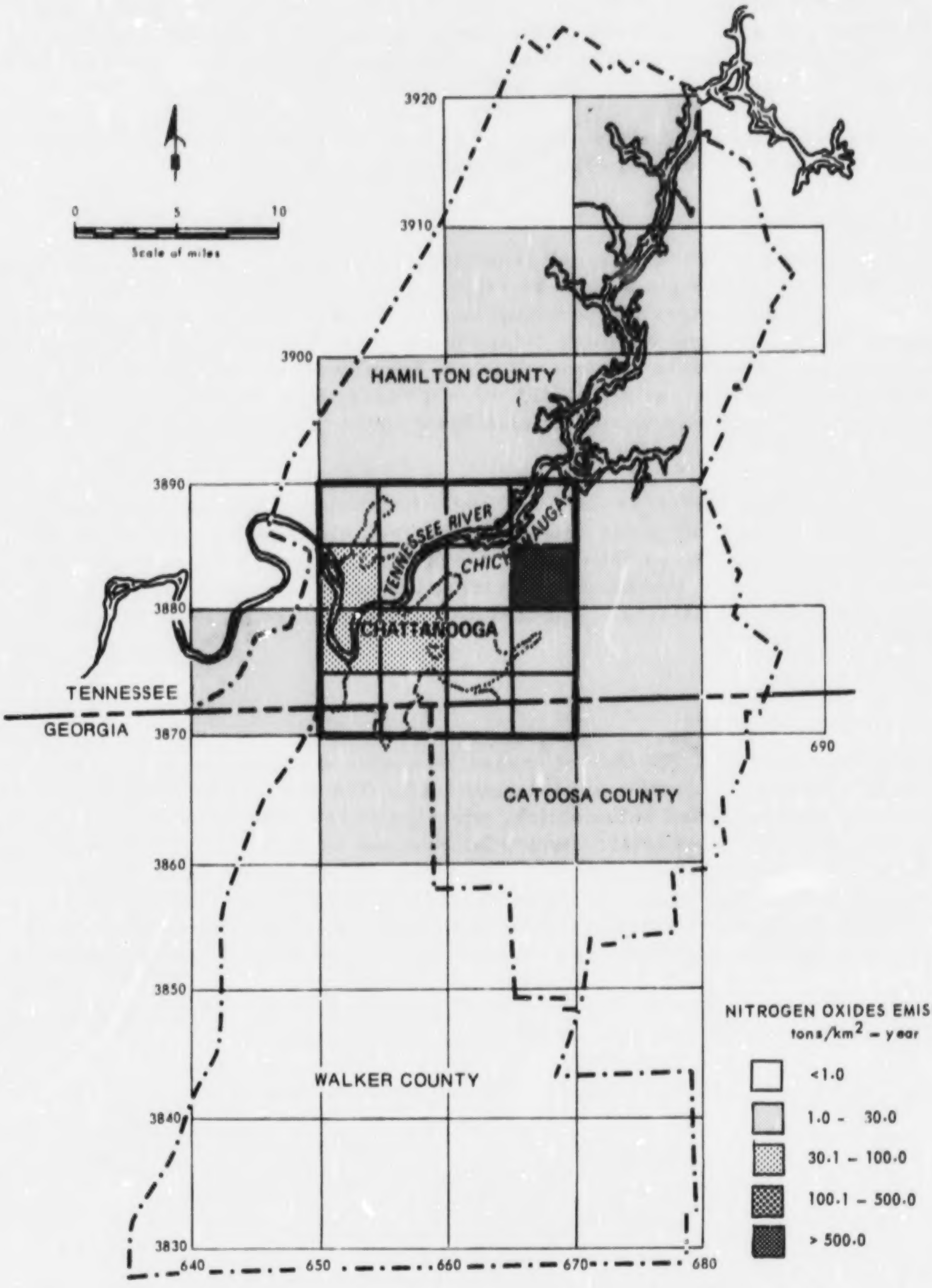

0
5
10
Scale of miles
3920
3910
3900
HAMILTON COUNTY
3890
TENNESSEE RIVER
CHIC
AUGA
3880
CHATTANOOGA
TENNESSEE
GEORGIA
3870
690
CATOOSA COUNTY
3860
3850
NITROGEN OXIDES EMISSIONS, tons/km² – year
<1.0
1.0 - 30.0
30.1 – 100.0
100.1 – 500.0
> 500.0
WALKER COUNTY
3840
3830
640
650
660
670
680

Figure 6-7. Nitrogen oxides emission density, 1968.

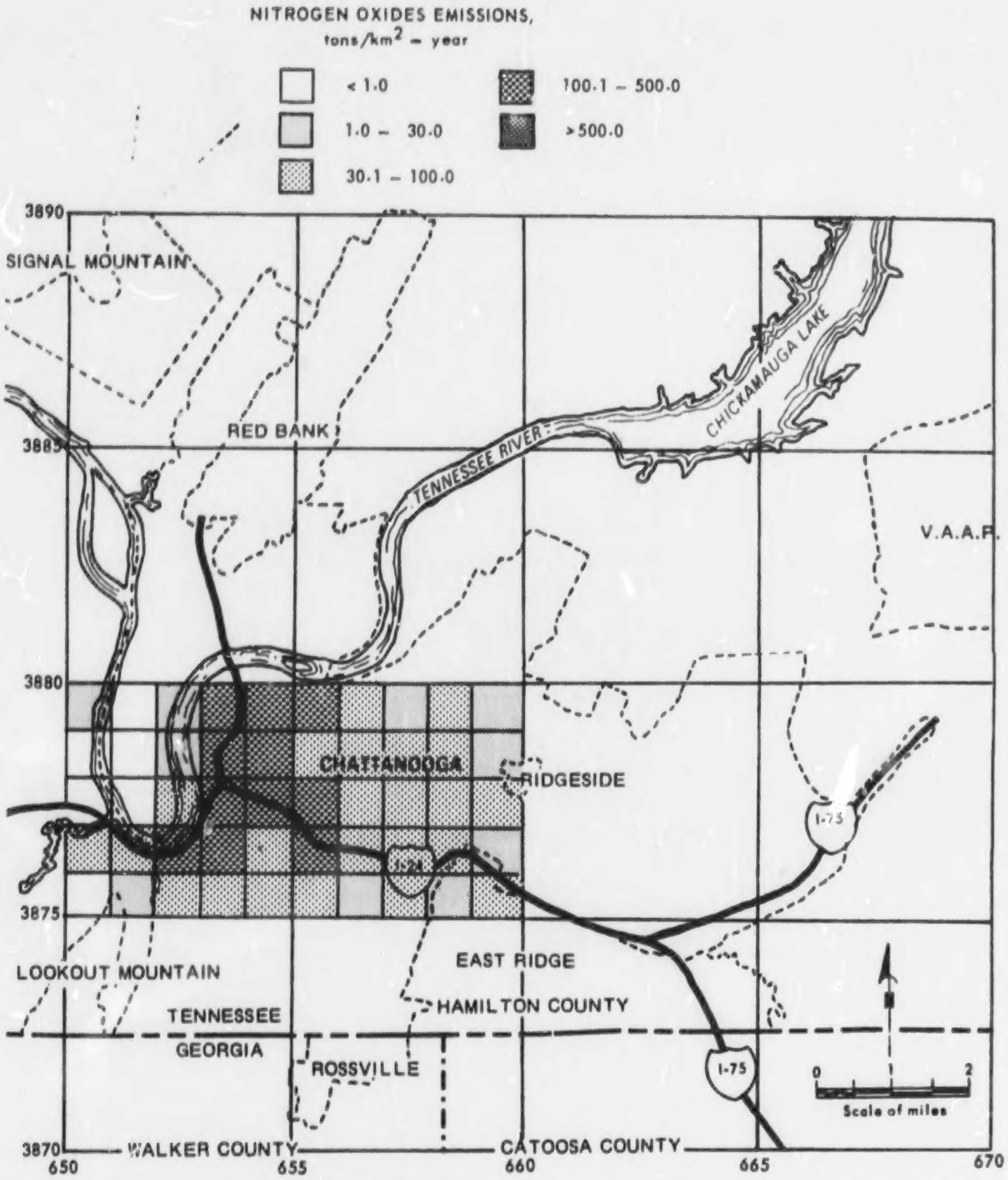

NITROGEN OXIDES EMISSIONS,
tons/km² – year
< 1.0
1.0 – 30.0
30.1 – 100.0
100.1 – 500.0
>500.0
3890
SIGNAL MOUNTAIN
RED BANK
3885
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
3880
CHATTANOOGA
RIDGESIDE
I-75
I-24
3875
LOOKOUT MOUNTAIN
EAST RIDGE
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
I-75
0
2
Scale of miles
3870
WALKER COUNTY
CATOOSA COUNTY
650
655
660
665
670

Figure 6-8. Nitrogen oxides emission density for 1-kilometer grids only.

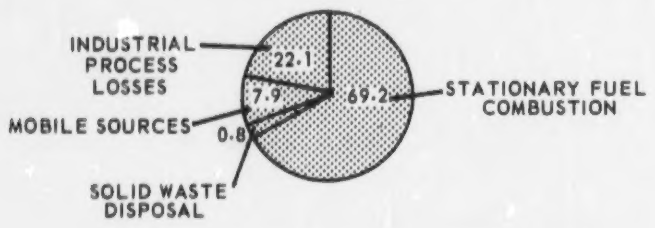


Figure 6-9. Percentage contribution of sulfur oxides by source category.

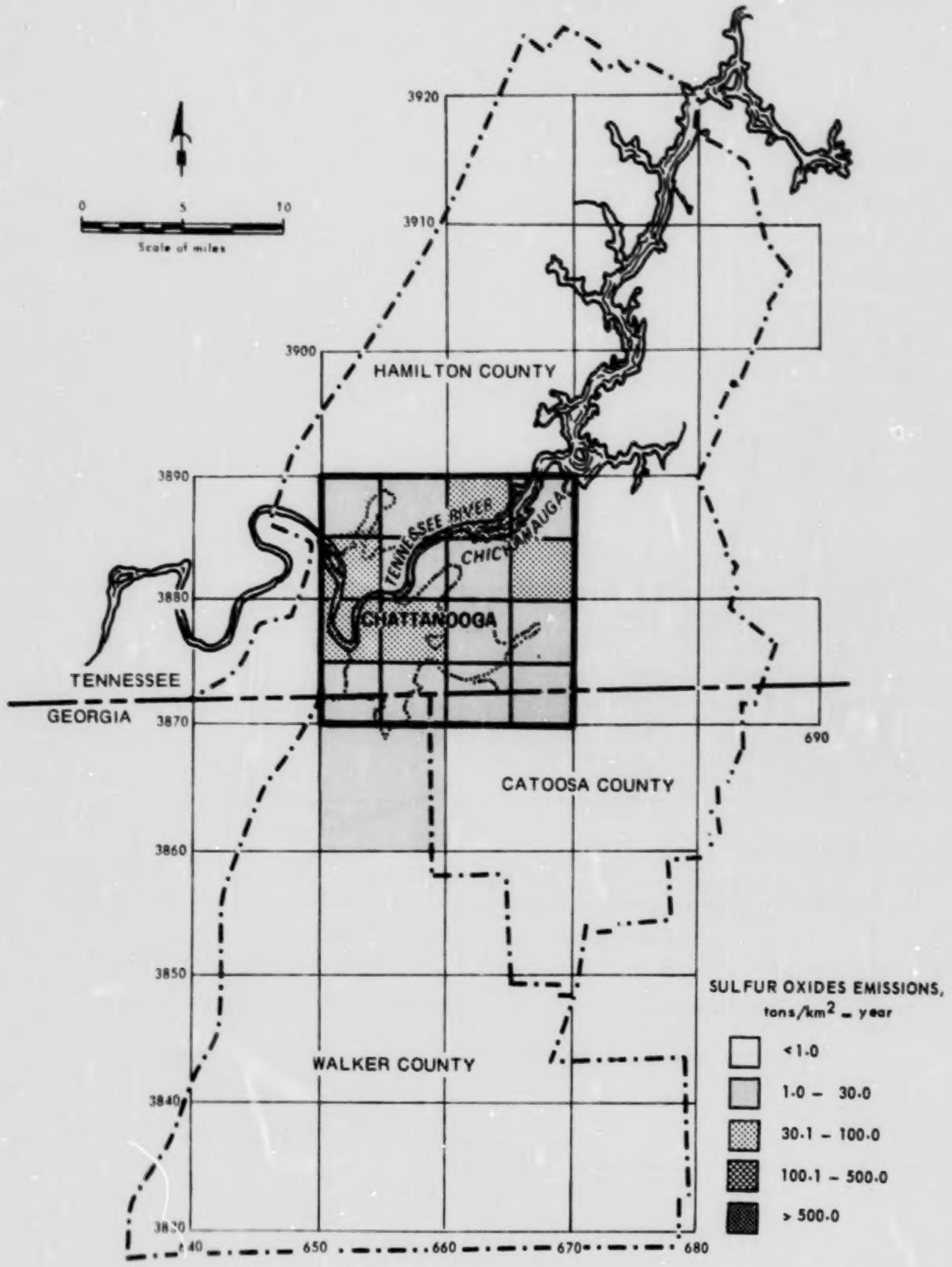

0
5
10
Scale of miles
3920
3910
3900
HAMILTON COUNTY
3890
TENNESSEE RIVER
CHICKAMAUGA
3880
CHATTANOOGA
TENNESSEE
GEORGIA
3870
690
CATOOSA COUNTY
3860
3850
WALKER COUNTY
3840
3830
640
650
660
670
680
SULFUR OXIDES EMISSIONS,
tons/km² – year
<1.0
1.0 – 30.0
30.1 – 100.0
100.1 – 500.0
> 500.0

Figure 6-10. Sulfur oxides emission density, 1968.

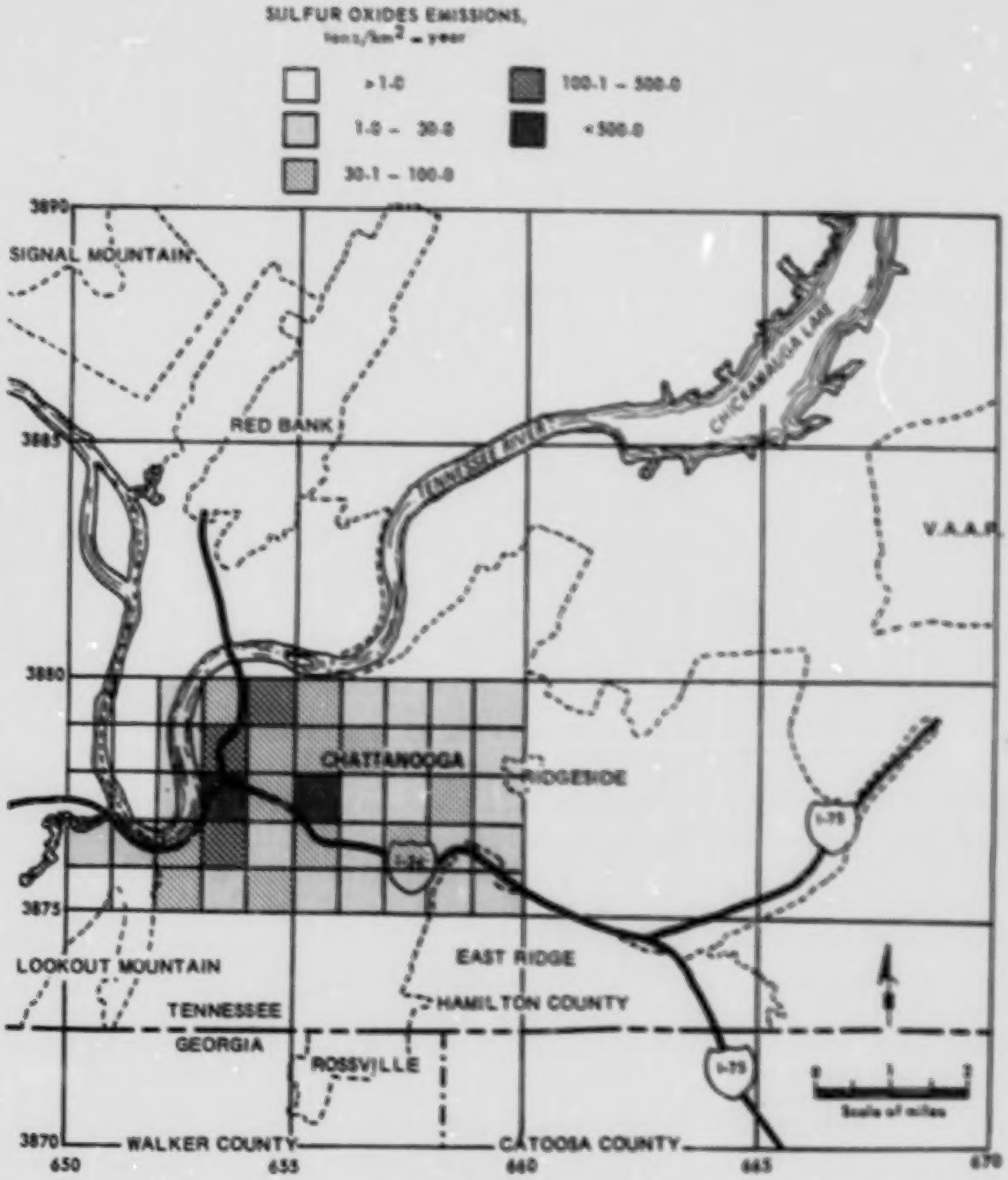

SULFUR OXIDES EMISSIONS,
tons/km² - year
>1.0
1.0 - 30.0
30.1 - 100.0
100.1 - 500.0
<500.0
3890
SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
3885
V.A.A.P.
3880
CHATTANOOGA
RIDGESIDE
I-75
I-24
3875
LOOKOUT MOUNTAIN
EAST RIDGE
TENNESSEE
HAMILTON COUNTY
GEORGIA
ROSSVILLE
I-75
0
1
2
Scale of miles
3870
WALKER COUNTY
CATOOSA COUNTY
650
655
660
665
670

Figure 6-11. Sulfur oxides emission density for 1-kilometer grids only.

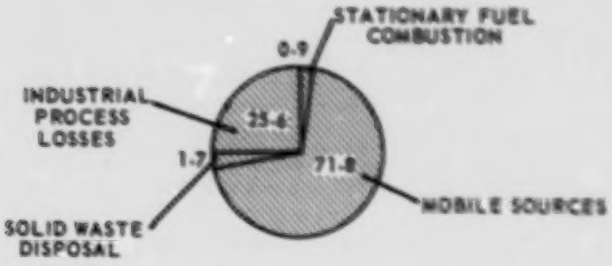


Figure 6-12. Percentage contribution of carbon monoxide by source category.

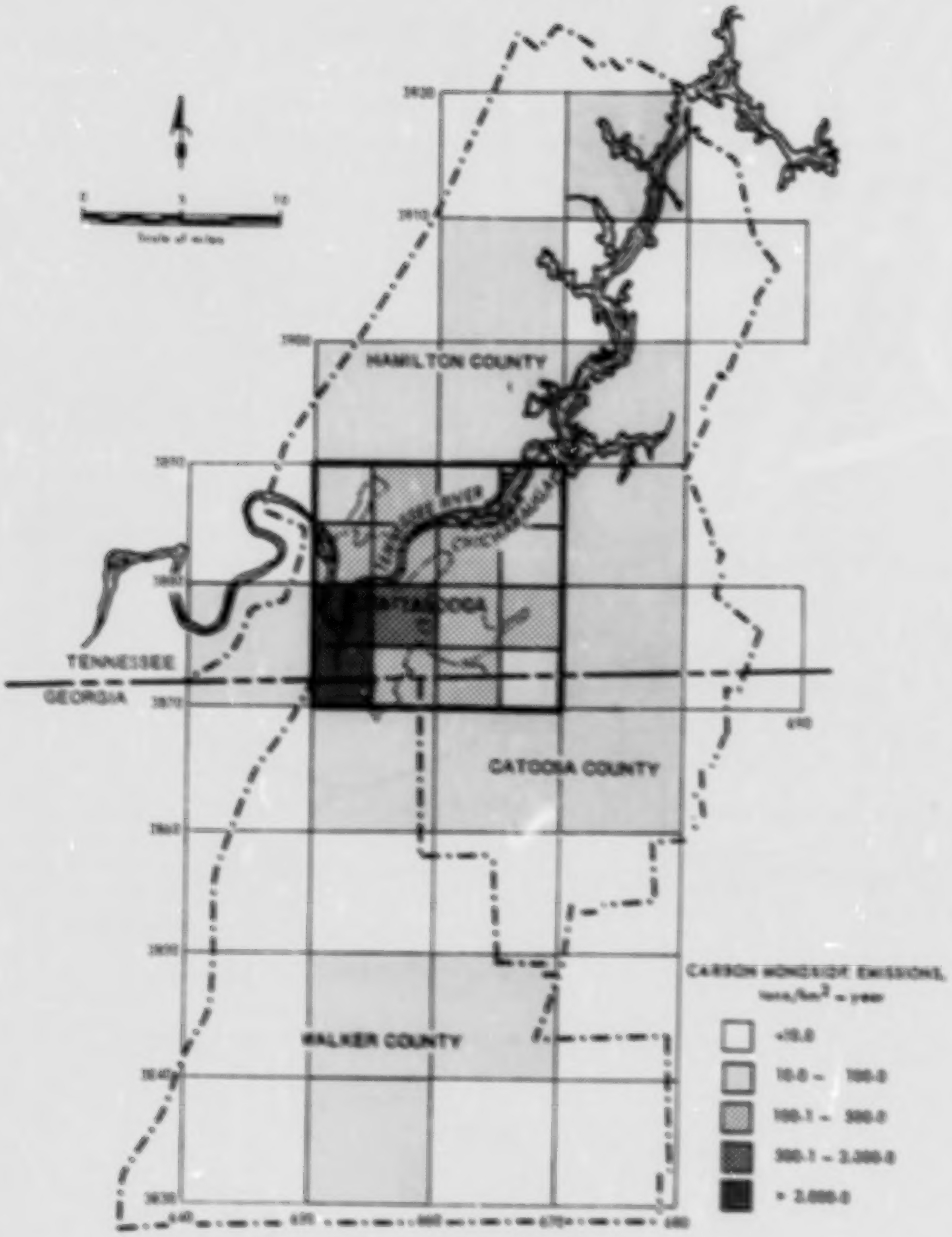

0 5 10
Scale of miles
3920
3910
3900
3890
3880
3870
3860
3850
3840
3830
640
650
660
670
680
690
HAMILTON COUNTY
TENNESSEE RIVER
CHICKAMAUGA
CHATTANOOGA
TENNESSEE
GEORGIA
CATOOSA COUNTY
WALKER COUNTY
CARBON MONOXIDE EMISSIONS,
tons/km^2 - year
<10.0
10.0 - 100.0
100.1 - 300.0
300.1 - 3,000.0
> 3,000.0

Figure 6-13. Carbon monoxide emission density, 1968.

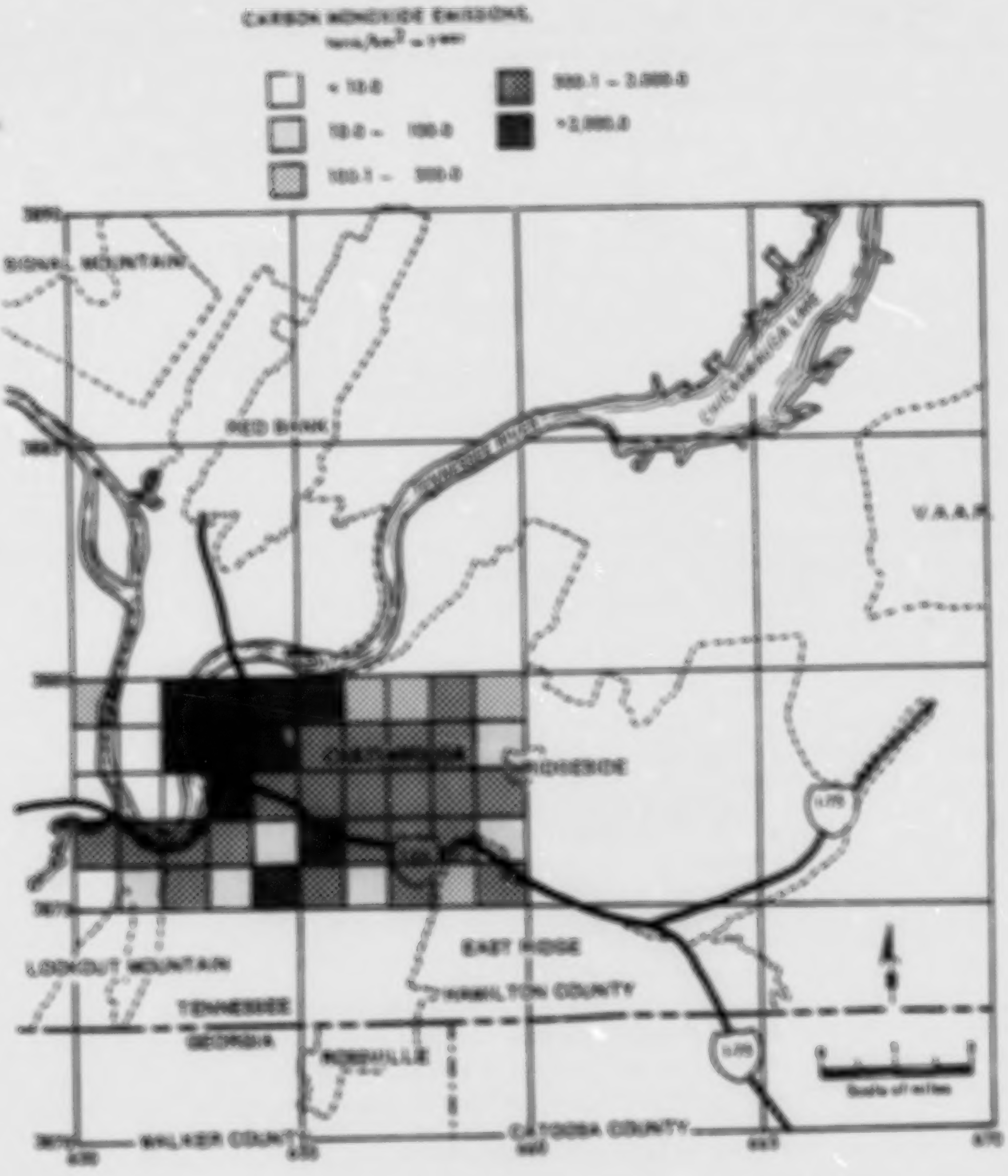

CARBON MONOXIDE EMISSIONS,
tons/km² × year
< 10.0
10.0 – 100.0
100.1 – 500.0
500.1 – 2,000.0
>2,000.0
SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
CHATTANOOGA
RIDGESIDE
I-75
EAST RIDGE
LOOKOUT MOUNTAIN
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
I-75
Scale of miles
WALKER COUNTY
CATOOSA COUNTY

Figure 6-14. Carbon monoxide emission density for 1-kilometer grids only.

6.2.5 Hydrocarbons

An estimated 32,300 tons of hydrocarbons were released in the study area during 1968. The major sources were gasoline-powered motor vehicles (55 percent). Other hydrocarbon emissions came from Solid Waste Disposal (18 percent), gasoline evaporation during handling and storage (15 percent), and solvent evaporation from dry cleaning, painting,and surface coating operations (9 percent). About 21 percent came from sources in Georgia.

Figure 6-15 illustrates the sources of hydrocarbon emissions and Figures 6-16 and 6-17 show the emission density by grids.

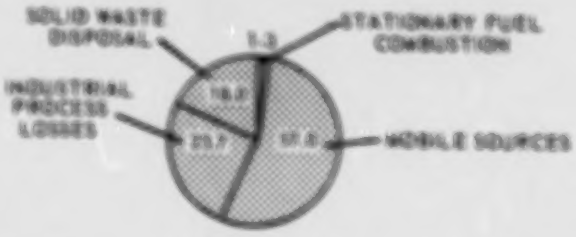


Figure 6-15. Percentage contribution of hydrocarbons by source category.

6.2.6 Acid Mist

An estimated 8,900 tons of sulfuric and nitric acid mist were released to the local atmosphere in the production of TNT and other chemicals. The sources of these emissions are all located in Hamilton County, Tennessee, west of the Missionary Ridge, where the concentration of these pollutants causes a severe, localized problem.

6.3 SUMMARY

The following quantities of pollutants were emitted in Hamilton County, Tennessee, and Walker County and Catoosa County, Georgia, during 1968.

Particulate matter	11,400 tons
Nitrogen oxides	31,500 tons
Sulfur oxides	9,300 tons
Carbon monoxide	213,700 tons
Hydrocarbons	32,300 tons
Acid mist	8,900 tons

Table 6-3 summarizes the percent contribution of all pollutants by source category. The Industrial Process Losses category is probably most important, contributing 44 percent of the particulate emissions, 22 percent of the sulfur oxide emissions, 58 percent of the nitrogen oxides, 24 percent of the hydrocarbons, and 26 percent of the carbon monoxide emissions for the area. Mobile Sources are important as contributors of nitrogen oxides (27 percent), hydrocarbons (57 percent), and carbon monoxide (72 percent). Stationary Fuel Combustion is an important contributor of particulate matter (32 percent) and sulfur oxides (69 percent).

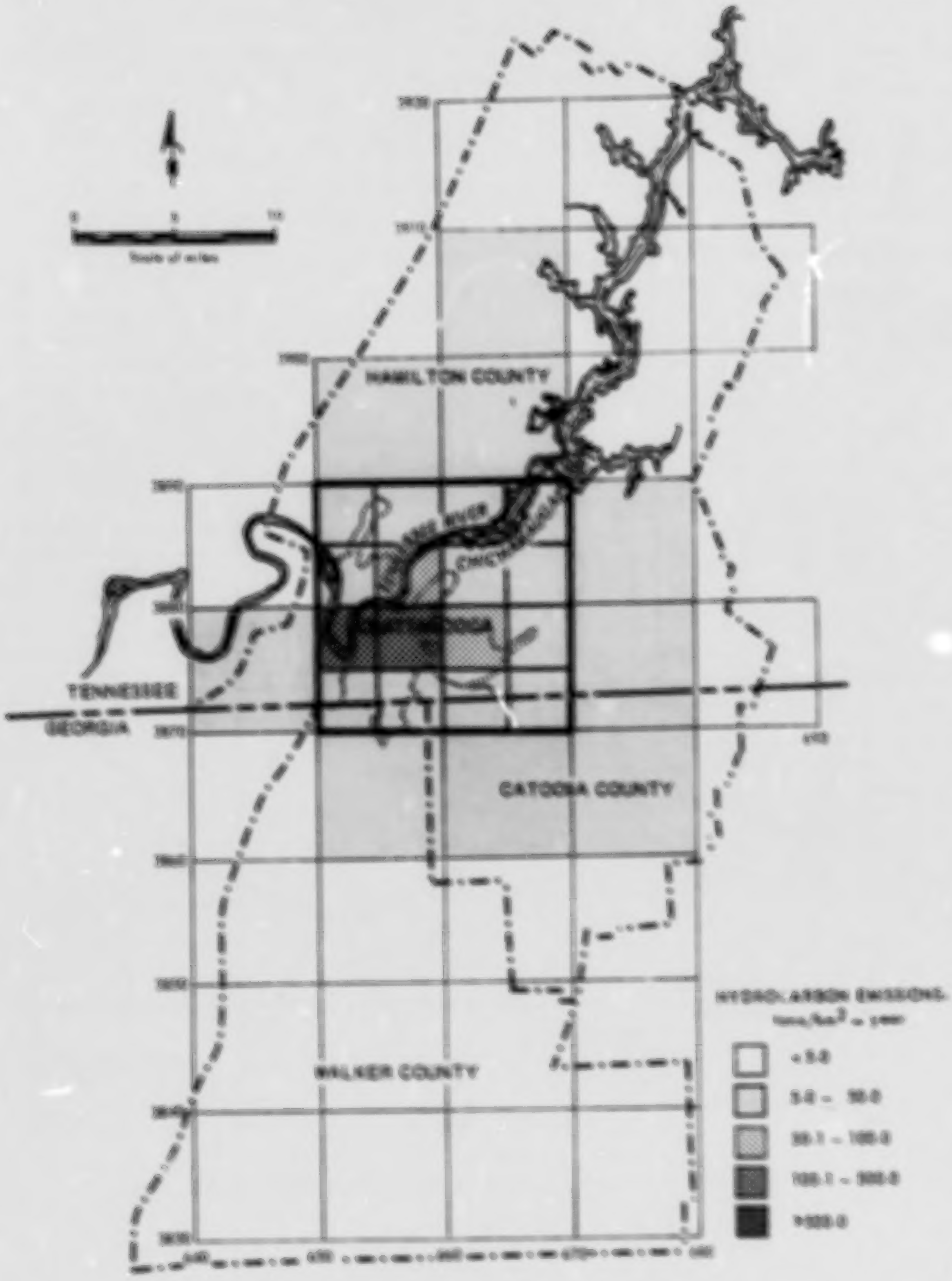

0 5 10
Scale of miles
HAMILTON COUNTY
TENNESSEE RIVER
CHICKAMAUGA
CHATTANOOGA
TENNESSEE
GEORGIA
CATOOSA COUNTY
WALKER COUNTY
HYDROCARBON EMISSIONS
tons/km^2 – year
< 5.0
5.0 – 50.0
50.1 – 100.0
100.1 – 500.0
>500.0

Figure 6-18. Hydrocarbons emission density, 1985.

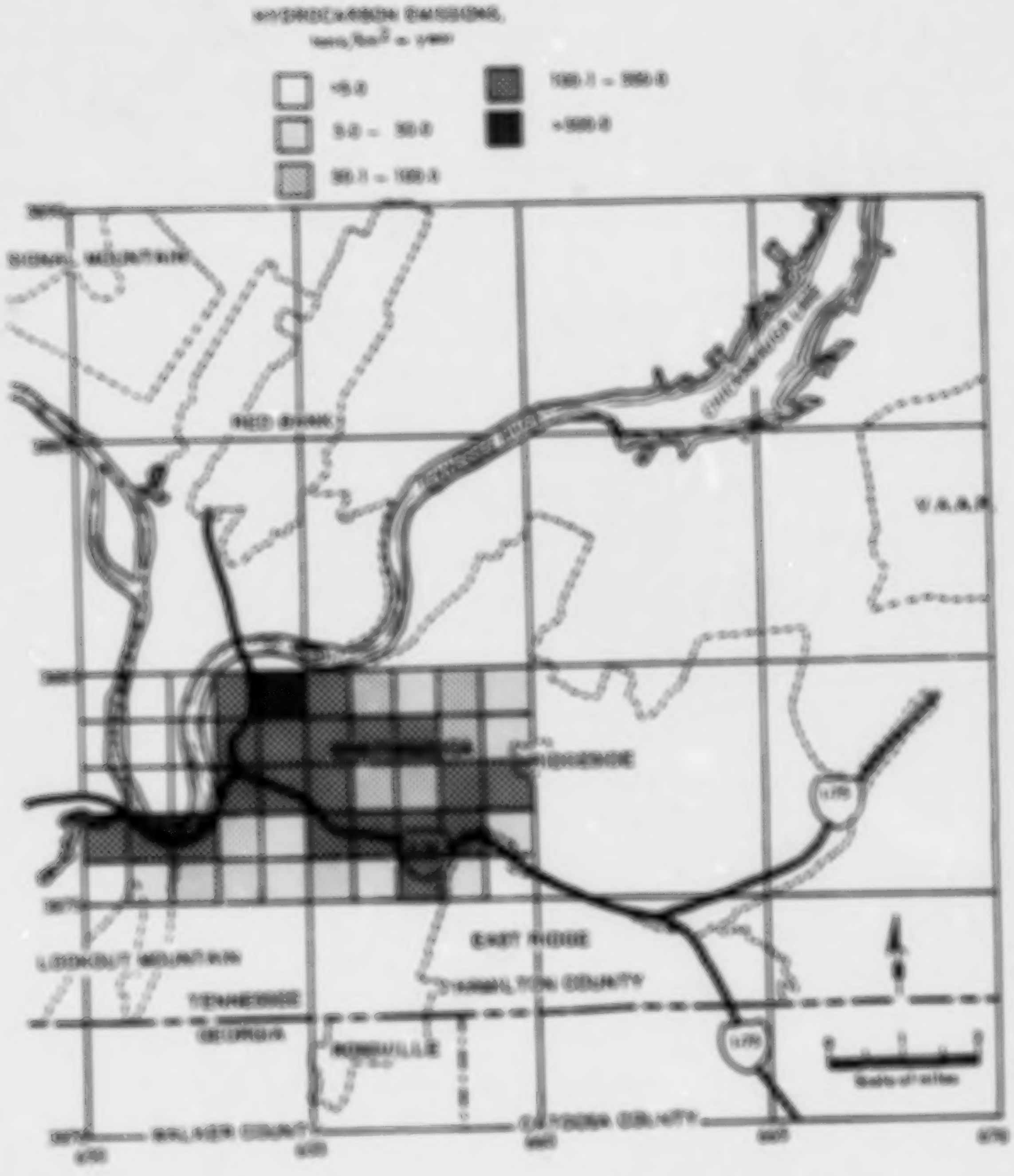

HYDROCARBON EMISSIONS, tons/km² x year
<5.0
5.0 – 50.0
50.1 – 100.0
100.1 – 500.0
>500.0
SIGNAL MOUNTAIN
RED BANK
TENNESSEE RIVER
CHICKAMAUGA LAKE
V.A.A.P.
CHATTANOOGA
RIDGESIDE
I-75
EAST RIDGE
LOOKOUT MOUNTAIN
HAMILTON COUNTY
TENNESSEE
GEORGIA
ROSSVILLE
WALKER COUNTY
CATOOSA COUNTY
Scale of miles

Figure 6-17. Hydrocarbons emission density for 1-kilometer grids only.

Table 6-2. CONTRIBUTION OF POLLUTANTS BY SOURCE CATEGORY, CHATTANOOGA METROPOLITAN AREA
(percent)

Source category	Particulate	SO_x	NO_x	HC	CO
Stationary fuel combustion					
Industrial	27.1	56.4	11.6	0.2	0.1
Commercial and governmental	3.0	5.1	0.5	0.3	0.2
Residential	1.6	6.7	1.0	0.8	0.6
Total	31.7	68.2	13.1	1.3	0.9
Mobile sources					
Gasoline	7.3	6.7	24.7	54.4	70.7
Diesel	1.8	0.8	1.3	0.8	-
Aircraft	0.3	-	0.5	1.5	1.1
Railroads	0.8	0.4	0.6	0.4	-
Total	10.2	7.9	27.1	57.1	71.8
Solid waste disposal					
Private incinerator	0.5	0.1	-	-	0.1
Burning dumps	8.7	0.3	0.7	5.2	0.8
Backyard burning	4.9	0.4	1.0	12.6	0.8
Total	14.1	0.8	1.7	17.8	1.7
Industrial process losses					
Manufacturing losses	44.0	23.1	58.1	-	25.6
Gasoline handling	-	-	-	15.2	-
Solvent losses	-	-	-	8.6	-
Total	44.0	23.1	58.1	23.8	25.6
Total	100.0	100.0	100.0	100.0	100.0

7. REFERENCES

1. Hosler, C. R. Low-Level Inversion Frequency in Contiguous United States. Monthly Weather Rev. 89:319-339. Sept. 1961.

2. Air Quality Criteria for Particulate Matter. U.S. Department of Health, Education, and Welfare. U.S. Public Health Service. National Air Pollution Control Administration, Raleigh, N. C. Publication No. AP-49. 1969.

3. Barker, K., *et al.* Air Pollution. World Health Organization, Geneva, Switzerland. 1961.

4. Katz, M. and G. D. Clayton. Instrumental and Analytical Techniques for Continuous Determination of Air Contaminants. Proc. of Am. Soc. for Testing Materials. 53:94-95. 1953.

5. An unofficial suspended particulate rating scale for soiling used by the State of New Jersey.

6. Air Quality Standards and Air Pollution Control Regulations for the St. Louis Metropolitan Area. Missouri Air Conservation Commission. Jefferson City, Missouri. March 24, 1967. 32 p.

7. Tennessee Air Pollution Control Regulations. Tennessee Department of Public Health. Division of Air Pollution Control. Nashville, Tennessee. August 9, 1969. 33 p.

8. Hemeon, W. C. L., G. F. Haines, and H. M. Ide. Determination of Haze and Smoke Concentrations by Filter Paper Samplers. Air Repair. 3(1):22. 1953.

9. Air Quality Criteria for Sulfur Oxides. U.S. Department of Health, Education, and Welfare. Public Health Service. National Air Pollution Control Administration, Raleigh, N. C. Publication No. AP-50. 1969.

10. Selected Methods for the Measurement of Air Pollutants. U.S. Department of Health, Education, and Welfare. Public Health Service. Division of Air Pollution. Cincinnati, Ohio. PHS Publication No. 999-AP-11. May 1965. 56 p.

11. Methods of Measuring and Monitoring Atmospheric SO_2. U.S. Department of Health, Education, and Welfare. Public Health Service. National Air Pollution Control Administration. Washington. D. C. Publication No. 999-AP-6. 1964.

12. Air Quality Data, 1966 Edition. Department of Health, Education, and Welfare. Public Health Service. National Air Pollution Control Administration, Raleigh, N. C. Publication No. APTD-68-9. 1968.

Preceding page blank

13. Effects Surveillance Project. Tabulation of Data, January to December, 1967. U.S. Department of Health, Education, and Welfare, Public Health Service, National Air Pollution Control Administration, Raleigh, N. C. 1967.

14. Upham, J. B. Atmospheric Corrosion Studies in Two Metropolitan Areas. U.S. Public Health Service. Presented at the 59th Annual Meeting of the Air Pollution Control Association, San Francisco, California, June 20-24, 1966.

15. Ajax, R. L., C. J. Conlee, and J. B. Upham. The Effects of Air Pollution on the Fading of Dyed Fabrics. U.S. Public Health Service. Accepted for publication in JAPCA, 1970.

16. A Study of Air Pollution in the Interstate Region of Lewiston, Idaho, and Clarkston, Washington. U.S. Department of Health, Education, and Welfare, Public Health Service, National Air Pollution Control Administration. Washington, D. C. Publication No. 999-AP-8. 1964.

17. Greenberg, L. and M. B. Jacobs. Corrosion Aspects of Air Pollution. American Paint J. 39:64-78. July 1955.

18. Vega, T. and C. J. Seymour. A Simplified Method for Determining Ozone Levels in Community Air Pollution Surveys. JAPCA. 11:28-44. January 1961.

19. Hindawi, I. J. Examination of Indigenous Vegetation in the Vicinity of the Volunteer Arsenal, Chattanooga, Tennessee. Report N ES-67.1. Effects Section, Abatement and Control Program, National Center for Air Pollution Control, Cincinnati, Ohio. April 1967.

20. Taylor, O. C. and G. M. Eaton. Suppression of Plant Growth by Nitrogen Dioxide. Plant Physiology. 41:132-135. 1966.

21. Taylor, O. C. Effect of Oxidant on Air Pollutants. J. Occupt. Med. 10:497-499. June 1968.

22. Hindawi, I. J., J. A. Dunning, and C. S. Brandt. Morphological and Microscopial Changes in Tobacco, Bean, and Petunia Leaves Exposed to Irradiated Automobile Exhaust. Phytopathology. 55(1):27-30. January 1965.

23. Heck, W. W. Discussion of O. C. Gaylor's paper: Effect of Oxidant Air Pollutants. J. Occupt. Med. 10:497-499. 1968.

24. Moyer, D. Effects of Air Pollution on Plants. World Health Organization, Monograph Series. No. 46, 1961. Columbia University Press, New York. 1961.

25. Prince, A. L., F. E. Bear, E. G. Brennan, I. A. Leone, and R. H. Daines. Soil Science. 67:269. 1949.

APPENDICES

A. METEOROLOGICAL INFORMATION
B. AIR QUALITY STATION INFORMATION
C. FREQUENCY DISTRIBUTIONS OF AIR QUALITY MEASUREMENTS
D. EMISSION INVENTORY INFORMATION

APPENDIX A. METEOROLOGICAL INFORMATION

A.1 METEOROLOGICAL SAMPLING SITES

Meteorological data were secured through the cooperation of commercial establishments, governmental agencies, and from NAPCA instrumentation installed specifically for the study. The exposure of each station is detailed in the following paragraphs. Wind systems were supported by aluminum towers and thermographs housed in standard Weather Bureau instrument shelters. Geographical location of the sensors is outlined in Table A-1.

Station 1 - Lookout Mountain

A wind system and thermograph were located on the roof of the upper terminal of the Lookout Mountain Incline Railway, a split-level flat roof structure, approximately 2200 feet above mean sea level (MSL). The main roof is a tarred and graveled concrete slab, covering a wide mall between shops and offices below.

The wind system was located on an elevated section of the roof until November 1967. At that time interference with a pre-existing radio facility forced its relocation to the lower roof section. A mast section was then added to compensate for the change in elevation. On January 24, 1968 the Climet Model C1-3 wind system was exchanged for a Cardian Model WV-1 system.

Such a mountaintop exposure should remain in the general windflow above most nocturnal inversions.

Station 2 - Ruby Falls

A thermograph was located in a grassed area northeast of the Ruby Falls building. This location provided a temperature measurement at approximately 1220 feet MSL.

Station 7 - Rossville, Georgia

A wind system and thermograph were located in a grassy, open area at the corner of Williams and Peerless Streets. The Climet Model C1-3 wind system was fixed atop a 32-foot tower. This site affords an excellent exposure for detecting movements within the valley.

Station 8 - National Guard

A thermograph was located in a graveled area of the Tennessee National Guard parking lot in the 1900 block of Holtzclaw Avenue. This large open area was also utilized for temperature-sounding work during the three intensive study periods. It can be considered representative of the metropolitan urban area.

Station 14 - Lovell Field

Hourly U. S. Weather Bureau observations of wind speed and direction were used from this site. The wind system is located along a taxiway, 20 feet off the

Preceding page blank

Table A-1. LOCATION OF METEOROLOGICAL SENSORS

Station number	Longitude, °W	Latitude, °N	Elevation, ft MSL	Address
1	85°20.6'	35°00.4'	Wind sensors-2200 Thermograph-2160	Incline Railway Terminal Building 827 East Brow Road, Lookout Mountain, Tennessee
2	85°20.4'	35°01.1'	Thermograph-1220	Ruby Falls, Lookout Mountain Highway, Chattanooga
7	85°17.6'	34°58.7'	Thermograph-665 Wind sensors-700	Mobile air sampling unit, Williams and Peerless Streets Rossville, Georgia (thermograph removed March 1968)
8	85°17.5'	35°01.4'	Thermograph-655	Office trailer; National Guard Armory 1901 Holtzclaw Avenue, Chattanooga
14[a]	85°11.8'	35°02.3'	Wind sensors-685 Thermograph-671	Chattanooga Municipal Airport (Lovell Field) Chickamauga, Tennessee
19[b]	85°09.2'	35°06.5'	Wind sensors-720	VAAP Pond-5 at dam, near Highway 58
51	85°18.5'	35°02.8'	Wind sensors-930 Thermograph-900	Volunteer Life Building, corner of Patton Street and Georgia Avenue, Chattanooga, Tennessee
161	85°10.2'	35°03.0'	Wind sensors-725	Shallowford Road at Hickory Valley Christian Church
181	85°09.7'	35°06.2'	Thermograph-850	Boynton Ridge near Silverdale Highway
182	85°09.4'	35°06.1'	Thermograph-720	Hickory Valley near Silverdale Highway

[a] Operated by ESSA.

[b] Operated by VAAP (Atlas Chemical Co.). (No site description is presented in this report).

ground. A thermograph was located on the tarred and graveled roof of the two-story terminal building.

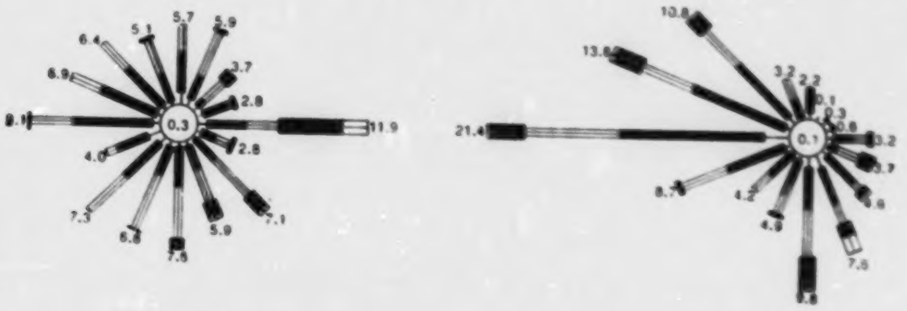
Station 51 - Volunteer Life

A wind system and thermograph were located on the tarred and graveled roof of the 12-story Volunteer Life Building in downtown Chattanooga. This site was selected because it was the tallest building in the area and as such should not have been influenced by nearby obstructions.

Station 161 - Hickory Valley

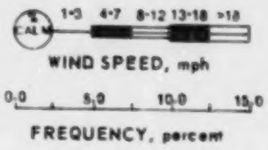
This Climet Model C1-3 wind system with a 32-foot tower was located approximately one-tenth mile north of Shallowford Road and three-tenths of a mile west of Hickory Valley Road. This location was established to record the flow patterns in the valley south of VAAP.

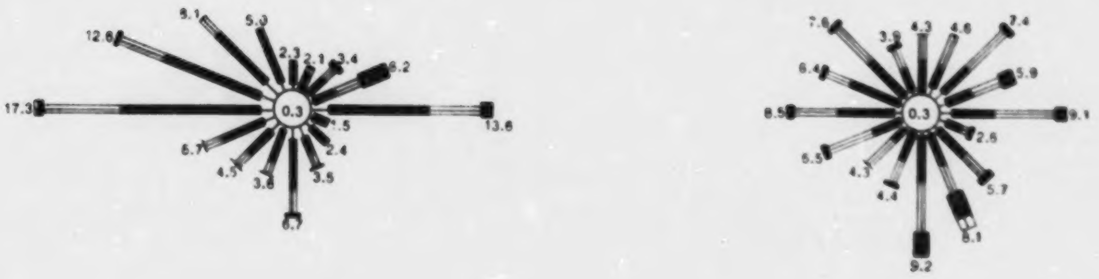
A.2 SEASONAL WIND PATTERNS AT METEOROLOGICAL SAMPLING SITES



FALL 1967
(SEP., OCT., NOV.)

SPRING 1968
(MAR., APR., MAY)

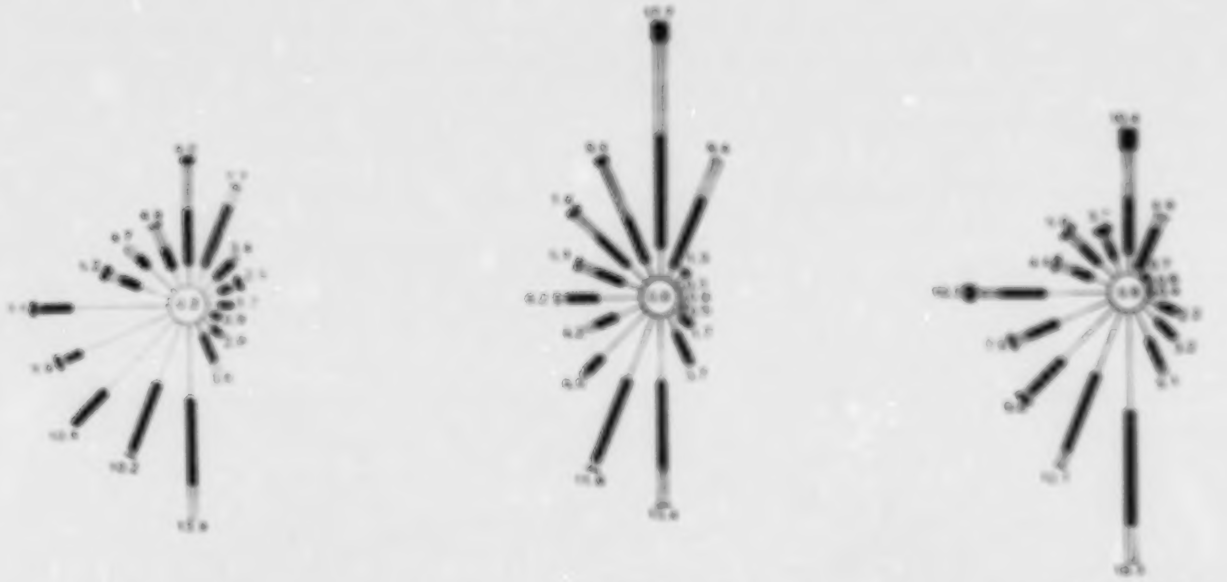




SUMMER 1968
(JUN., JUL., AUG.)

FALL 1968
(SEP., OCT., NOV.)

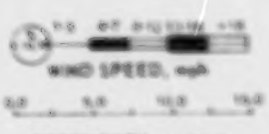
Lookout Mountain No. 1

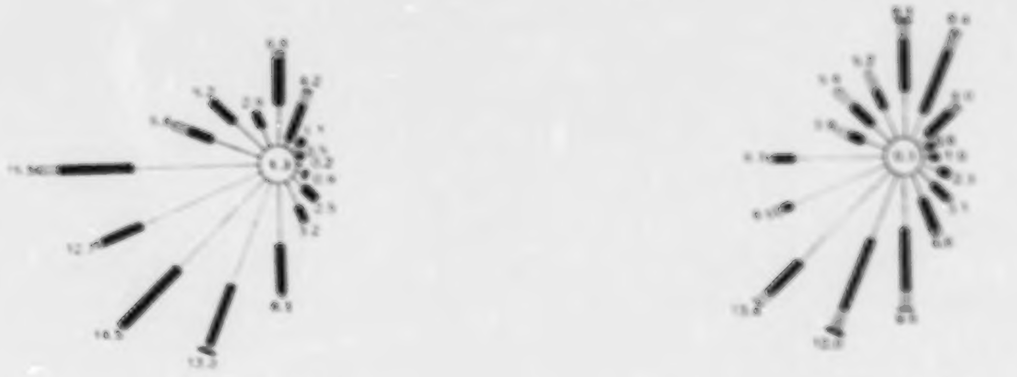


FALL 1967
(NOV., DEC.)

WINTER 1967-68
(DEC., JAN., FEB.)

SPRING 1968
(MAR., APR., MAY)

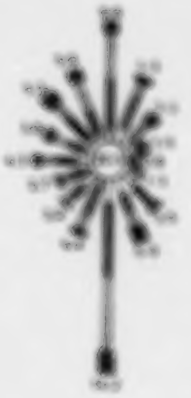




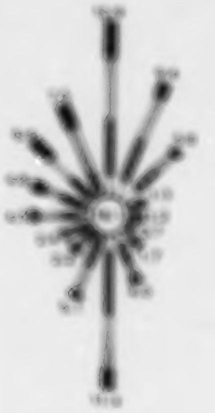
SUMMER 1968
(JUN., JUL., AUG.)

FALL 1968
(SEP., OCT., NOV.)

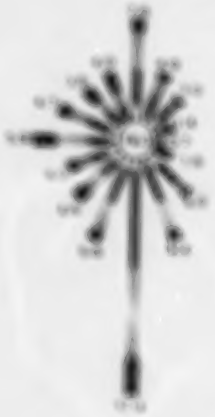
Rossville, Ga. No. 7



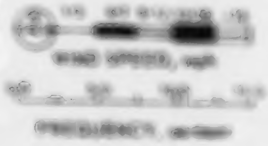
FALL 1967
(SEP., OCT., NOV.)

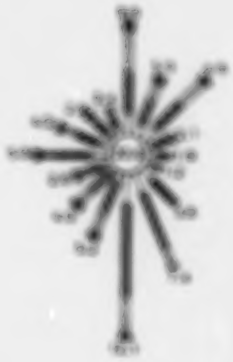


WINTER 1967-68
(DEC., JAN., FEB.)

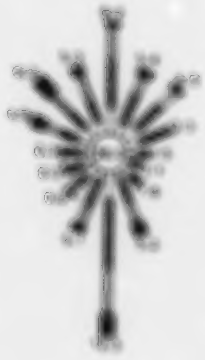


SPRING 1968
(MAR., APR., MAY)

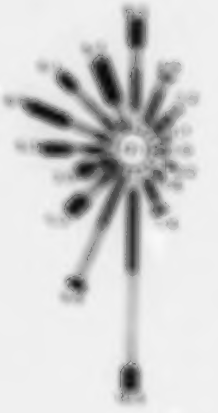

WIND SPEED, mph
FREQUENCY, percent



SUMMER 1968
(JUN., JUL., AUG.)

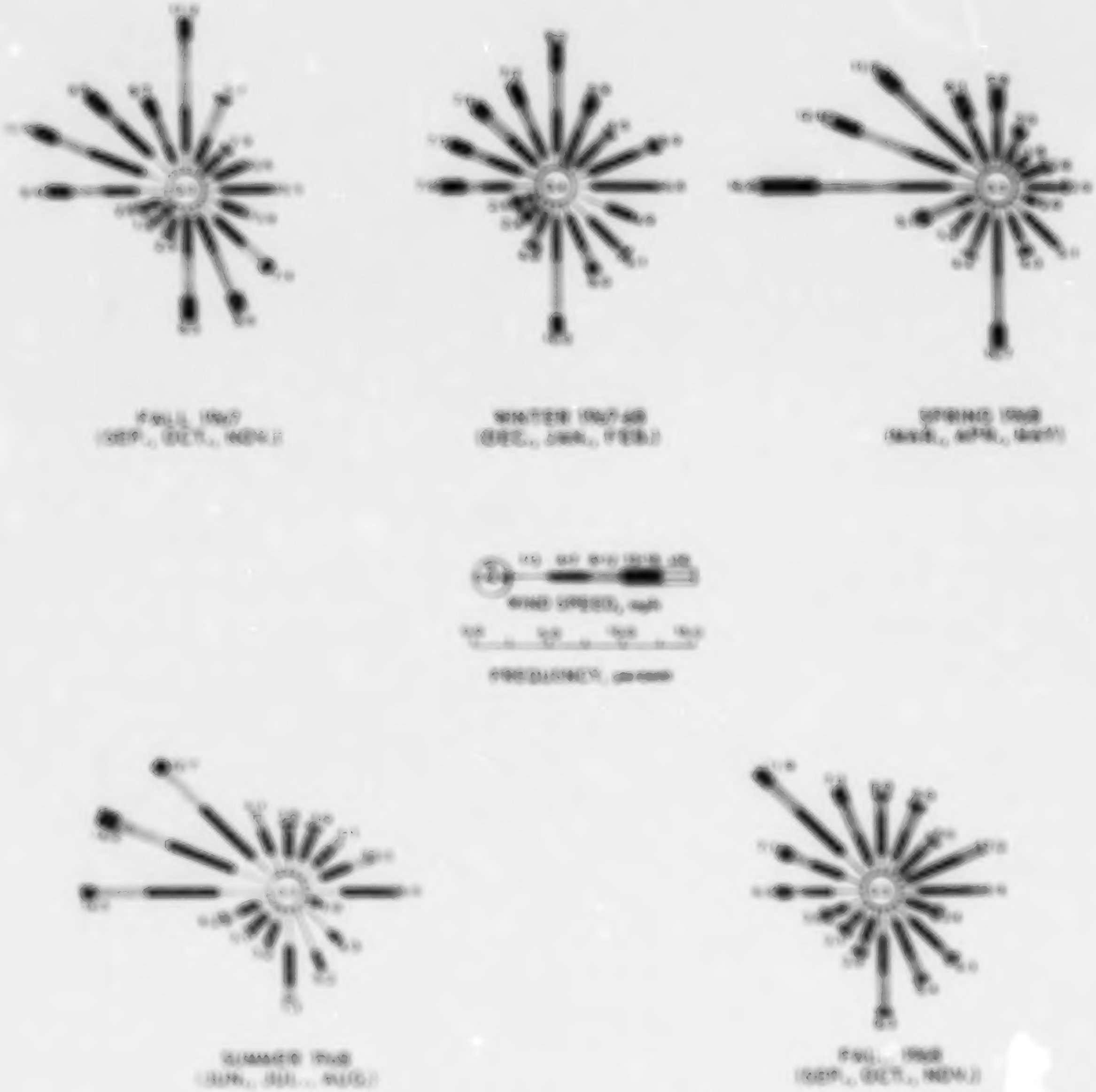


FALL 1968
(SEP., OCT., NOV.)



WINTER 1968
(DEC.)

Lovell Field No. 14



FALL 1967
(SEP., OCT., NOV.)

WINTER 1967-68
(DEC., JAN., FEB.)

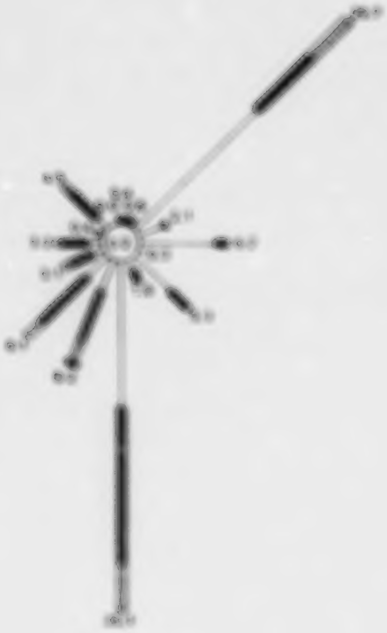
SPRING 1968
(MAR., APR., MAY)

SUMMER 1968
(JUN., JUL., AUG.)

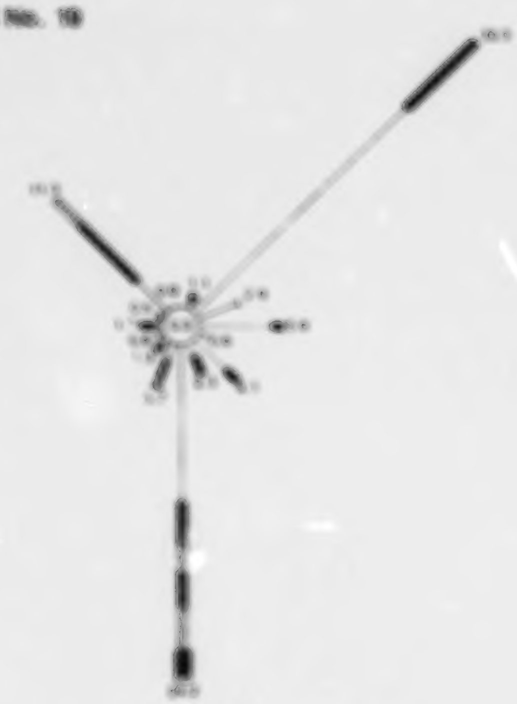
FALL 1968
(SEP., OCT., NOV.)

Volunteer Life Building No. 51

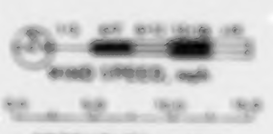
V.A.A.P. Pond No. 19

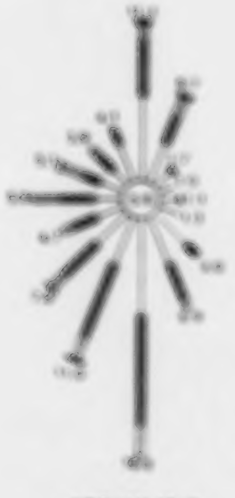


SUMMER 1968
(JUN., JUL., AUG.)

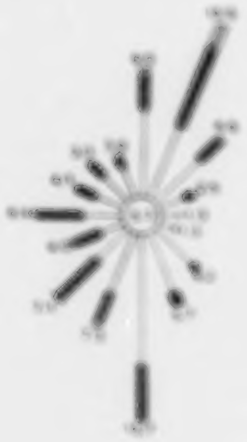


FALL 1968
(SEPT., OCT., NOV.)

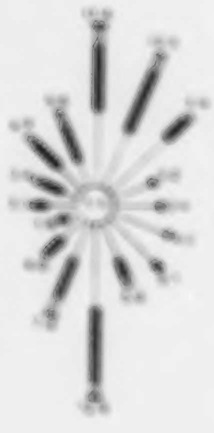

WIND SPEED, mph
FREQUENCY, percent



SPRING 1968
(MAR., APR., MAY)



SUMMER 1968
(JUN., JUL., AUG.)



FALL 1968
(SEPT., OCT., NOV.)

Hickory Valley No. 101

APPENDIX B.

AIR QUALITY STATION INFORMATION

Preceding page blank

Table B-1. AIR QUALITY SAMPLING STATION DESCRIPTION

Station number	Name	Sulfur dioxide	Suspended particulates	Oxidant	Nitric oxide^{f,g}	Nitrogen dioxide^{g}
1	Lookout Mountain	-	10/67 - 11/69	-	-	-
2	Ruby Falls	-	10/67 - 11/69	-	-	-
3	Water Stations	-	10/67 - 11/69	-	-	-
4	WDEF-TV	[illegible]	10/67 - 11/69	-	-	-
5	Federal Building	[illegible] [illegible]	d	[illegible]	-	[illegible]
6	North Chattanooga	-	10/67 - 11/69	-	-	-
7	Rossville	[illegible]	10/67 - 11/69	[illegible]	-	[illegible]
8	National Guard	[illegible] [illegible]	10/67 - 11/69	[illegible]	-	-
9	East Chattanooga	[illegible]	10/67 - 11/69	[illegible]	-	-
10	St. Jude	-	10/67 - 11/69	-	-	-
11	Missionary Ridge	-	10/67 - 11/69	-	-	-
12	Cloud Springs	-	10/67 - 11/69	-	-	-
13	Brainerd	-	10/67 - 11/69	-	-	-
14	Lovell Field	-	10/67 - 11/69	-	-	-
15	B. T. Washington	-	10/67 - 11/69	[illegible]	-	[illegible]
16	E. Brainerd	-	10/67 - 11/69	[illegible]	-	[illegible]
17	VAAP Administration^{e}	[illegible]	d	-	[illegible]	[illegible]
18	Farmer's Chemical	-	10/67 - 11/69	-	-	-
19	VAAP Pond 2^{e}	[illegible]	d	-	[illegible]	[illegible]
20	VAAP Rod and Gun^{e}	[illegible]	d	-	[illegible]	[illegible]
21	VAAP Harrison School^{e}	[illegible]	d	-	[illegible]	[illegible]
22	Signal Mountain	-	11/67 - 11/69	-	-	-
23	South Crest	-	-	-	-	-
24	Bell Telephone	-	11/67 - 11/69	-	-	-
25	East Rossville	-	6/69 - 11/69	-	-	-
26	Pine Ridge Road	-	-	-	-	-
27	Golden Gateway	[illegible]	5/69 - 11/69	[illegible]	[illegible]	[illegible]
101	Hickory Valley	-	-	-	[illegible]	[illegible]
102	FHS Rod and Gun	-	-	[illegible]	-	[illegible]
103	Rossville Health Department	-	d	-	-	[illegible]

Carbon monoxide was measured at station #5 from [illegible] through [illegible], and at station #27 from [illegible] through [illegible].
Hydrocarbon was measured at station #27 from [illegible] through [illegible].

[a] West-Gaeke, 2-hour bubblers.
[b] Conductivity - continuous.
[c] West-Gaeke - continuous (colorimetric).
[d] These data were collected as part of I.S.P. "Effects package" network and are available for the entire project period.
[e] These stations were operated by VAAP.
[f] Measured as the difference between NO_2 and NO_x - total oxides of nitrogen.
[g] Saltzman - colorimetric - continuous.
[h] Coulometric.
[i] Colorimetric - buffered potassium iodide.

Table B-2. AIR QUALITY SAMPLING STATIONS

Station number	Station name and address	Longitude, west		Latitude, north		United Transverse Mercator coordinates		Elevation, ft MSL
		Degrees	Minutes	Degrees	Minutes	Easting, km	Northing, km	
1	Lookout Mountain 417 East Brow Road Lookout Mountain, Tenn.	85	20.8	35	00.4	651.2	3,874.0	2,080
2	Ruby Falls Lookout Mountain Highway Lookout Mountain, Tenn.	85	20.4	35	01.1	651.5	3,876.2	1,290
3	Motor Brothers Highway 193 Blowing Springs, Ga.	85	20.1	34	58.5	652.1	3,871.3	670
4[a]	WDEF-TV 3300 Broad Street Chattanooga, Tenn.	85	19.3	35	03.0	653.0	3,876.1	675
5[a]	Federal Building 9th and Georgia Avenue Chattanooga, Tenn.	85	18.5	35	02.7	654.3	3,879.2	705
6[a]	North Chattanooga 1331 Dallas Road Chattanooga, Tenn.	85	18.2	35	04.7	654.6	3,882.0	1,040
7	Rossville Williams and Peerless Streets Rossville, Ga.	85	17.6	34	58.7	655.6	3,871.4	665
8	National Guard 1801 Holtzclaw Chattanooga, Tenn.	85	17.5	35	01.4	655.9	3,876.6	655
9[a]	East Chattanooga Bragg and Dodson Streets Chattanooga, Tenn.	85	15.4	35	03.7	659.0	3,881.0	690
10	St. Jude Ashland Terrace Chattanooga, Tenn.	85	13.9	35	06.9	658.1	3,887.0	780
11	Missionary Ridge 54 North Crest Road Chattanooga, Tenn.	85	15.4	35	02.8	658.1	3,877.1	1,040

Table B-2 (continued). AIR QUALITY SAMPLING STATIONS

Station number	Station name and address	Longitude, west		Latitude, north		United Transverse Mercator coordinates		Elevation, ft MSL
		Degrees	Minutes	Degrees	Minutes	Easting, km	Northing, km	
12	Cloud Springs Highway 146 Cloud Springs, Ga.	85	15.0	34	57.6	659.3	3,870.2	780
13^{a}	Brainerd 420 Shawnee Trail Chattanooga, Tenn.	85	13.5	35	01.5	661.5	3,877.0	670
14	Lovell Field (Municipal Airport) Chattanooga, Tenn.	85	11.8	35	02.3	664.5	3,878.7	700
15	B. T. Washington (Off Highway 58) Lake Hills, Tenn.	85	10.7	35	05.3	666.1	3,884.3	740
16	East Brainerd East Brainerd Road at Graysville Road East Brainerd, Tenn.	85	09.0	35	00.3	665.8	3,874.9	680
17^{b}	VAAP Administration Route 2A Tyner, Tenn.	85	09.4	35	04.5	666.3	3,882.6	750
18	Farmer's Chemical Highway 58 Tyner, Tenn.	85	09.6	35	06.1	667.7	3,885.5	760
19^{b}	VAAP Pond 5 Route 58 Tyner, Tenn.	85	09.2	35	06.5	668.5	3,886.6	690
20^{b}	VAAP Rod and Gun Hickory Valley Road Harrison Bay, Tenn.	85	08.6	35	07.5	668.8	3,888.3	770
21^{b}	VAAP Harrison School Route 58 Harrison Bay, Tenn.	85	08.3	35	06.6	669.3	3,888.5	760
22	Signal Mountain 212 South Palisades Drive Signal Mountain, Tenn.	85	20.8	35	06.6	650.7	3,886.3	1.700

Table B-2 (continued). AIR QUALITY SAMPLING STATIONS

Station number	Station name and address	Longitude, west		Latitude, north		United Transverse Mercator coordinates		Elevation, ft MSL
		Degrees	Minutes	Degrees	Minutes	Easting, km	Northing, km	
23	South Crest 198 South Crest Road Chattanooga, Tenn.	85	15.9	35	01.0	658.8	3,877.0	980
24	Bell Telephone St. Elmo Avenue Chattanooga, Tenn.	85	19.8	34	59.5	652.7	3,874.0	650
25	East Rossville Richmond Avenue Rossville, Georgia	85	17.4	34	58.0	656.2	3,871.5	800
26	Pine Ridge Pine Ridge Road Chattanooga, Tenn.	85	18.8	35	04.2	653.3	3,882.1	775
27	Golden Gateway 12th Street Chattanooga, Tenn.	85	18.7	35	02.6	653.7	3,879.0	700
161	Hickory Valley Shallowford Road Chattanooga, Tenn.	85	10.2	35	03.0	667.0	3,879.7	700
201	PHS Rod and Gun Hickory Valley Road Harrison Bay, Tenn.	85	08.6	35	07.5	668.8	3,888.3	780
107	Same as station number 19							
108	Same as station number 17							
109	Same as station number 21							
110	Same as station number 20							
140	Same as station number 5							
141	Rossville Health Department Suggs Street Rossville, Ga.	85	17.5	34	57.7	655.5	3,870.4	700

[a] These stations were at or near stations used for the 1963 study.

[b] These stations were operated by Volunteer Army Ammunition Plant (Atlas Chemical Co.).

APPENDIX C.

FREQUENCY DISTRIBUTIONS OF AIR QUALITY MEASUREMENTS

Preceding page blank

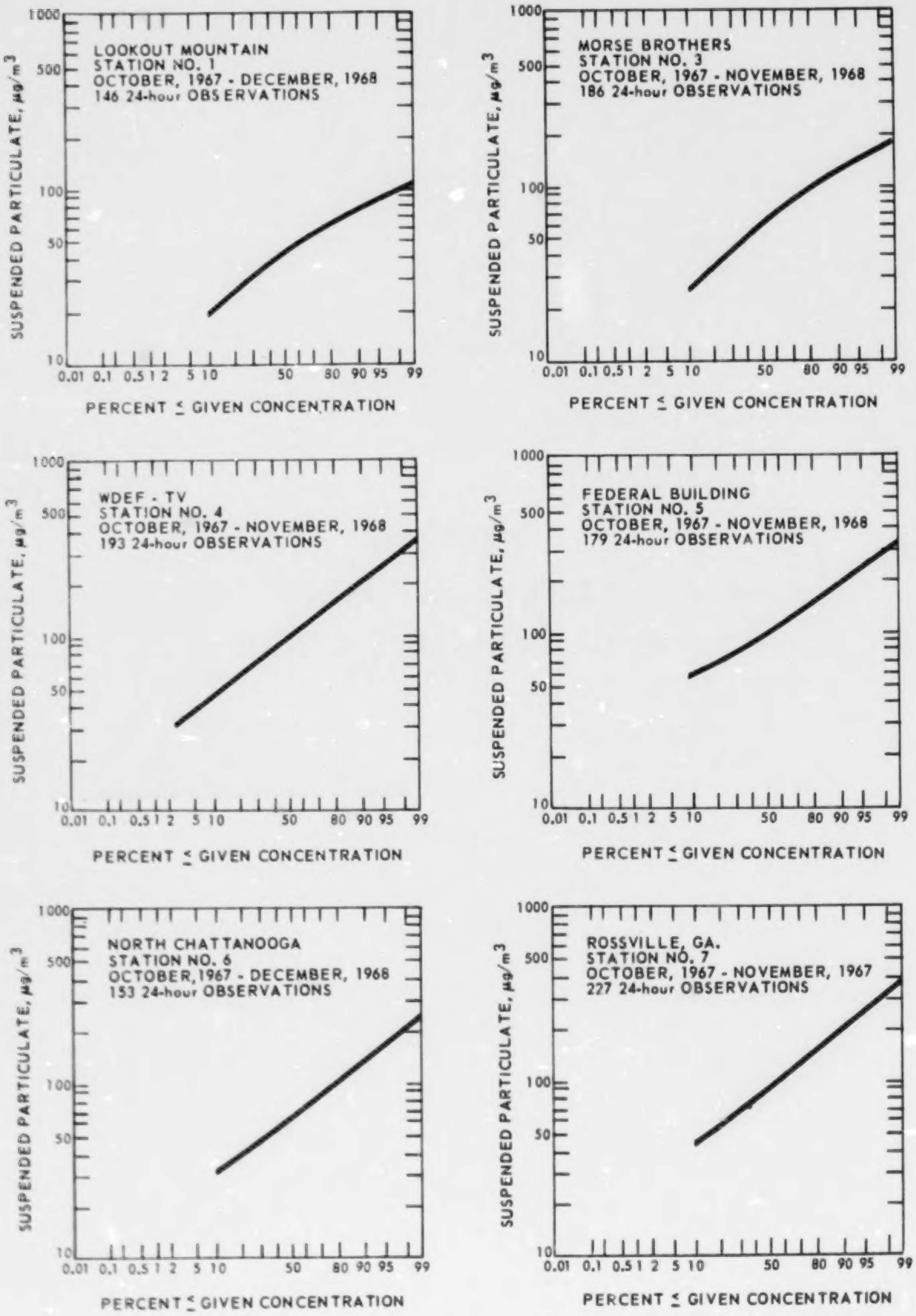


Figure C-1. Daily suspended particulate cumulative frequency distribution for sampling stations 1, 3, 4, 5, 6, and 7.

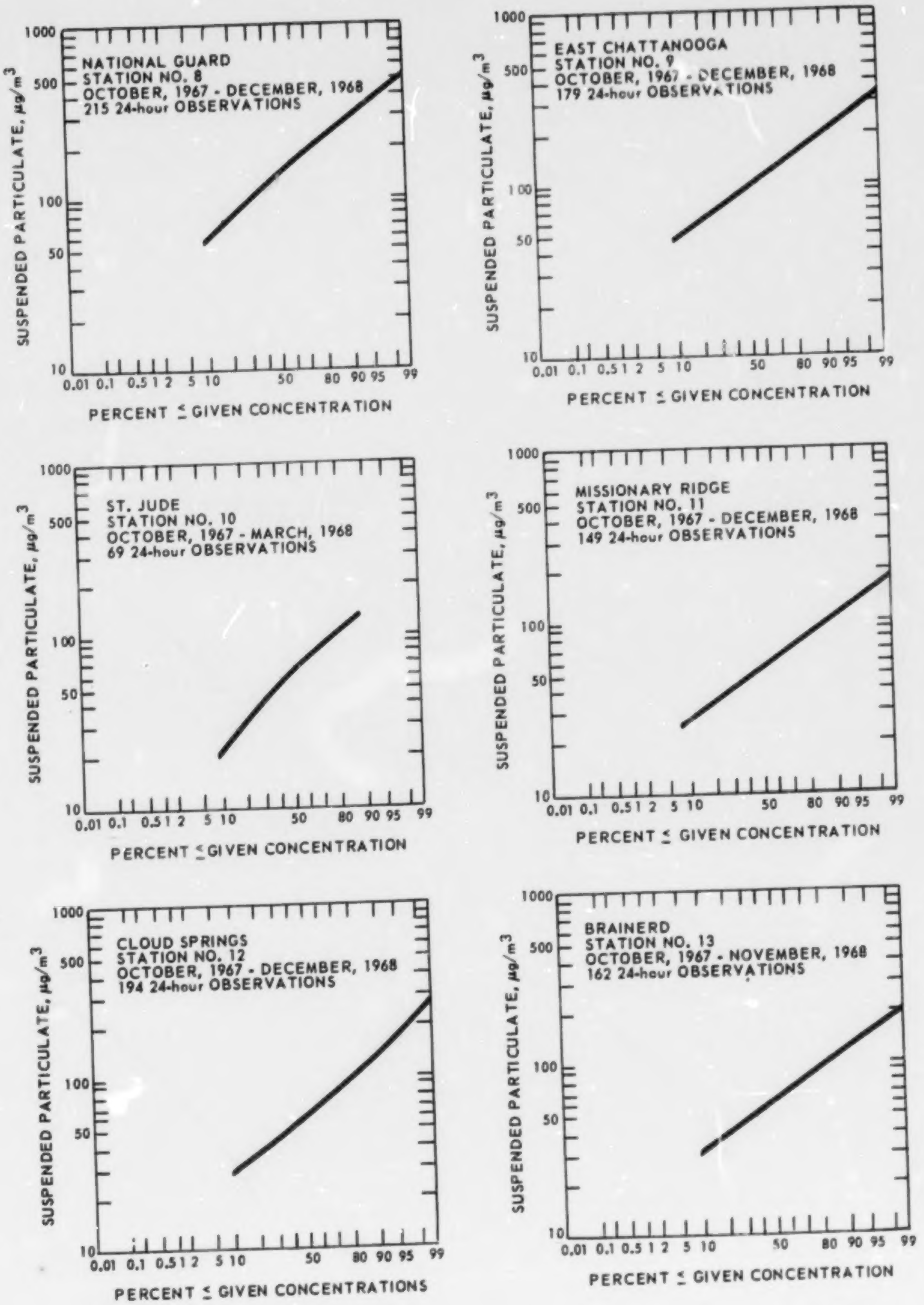


Figure C-2. Daily suspended particulate cumulative frequency distribution for sampling stations 8, 9, 10, 11, 12, and 13.

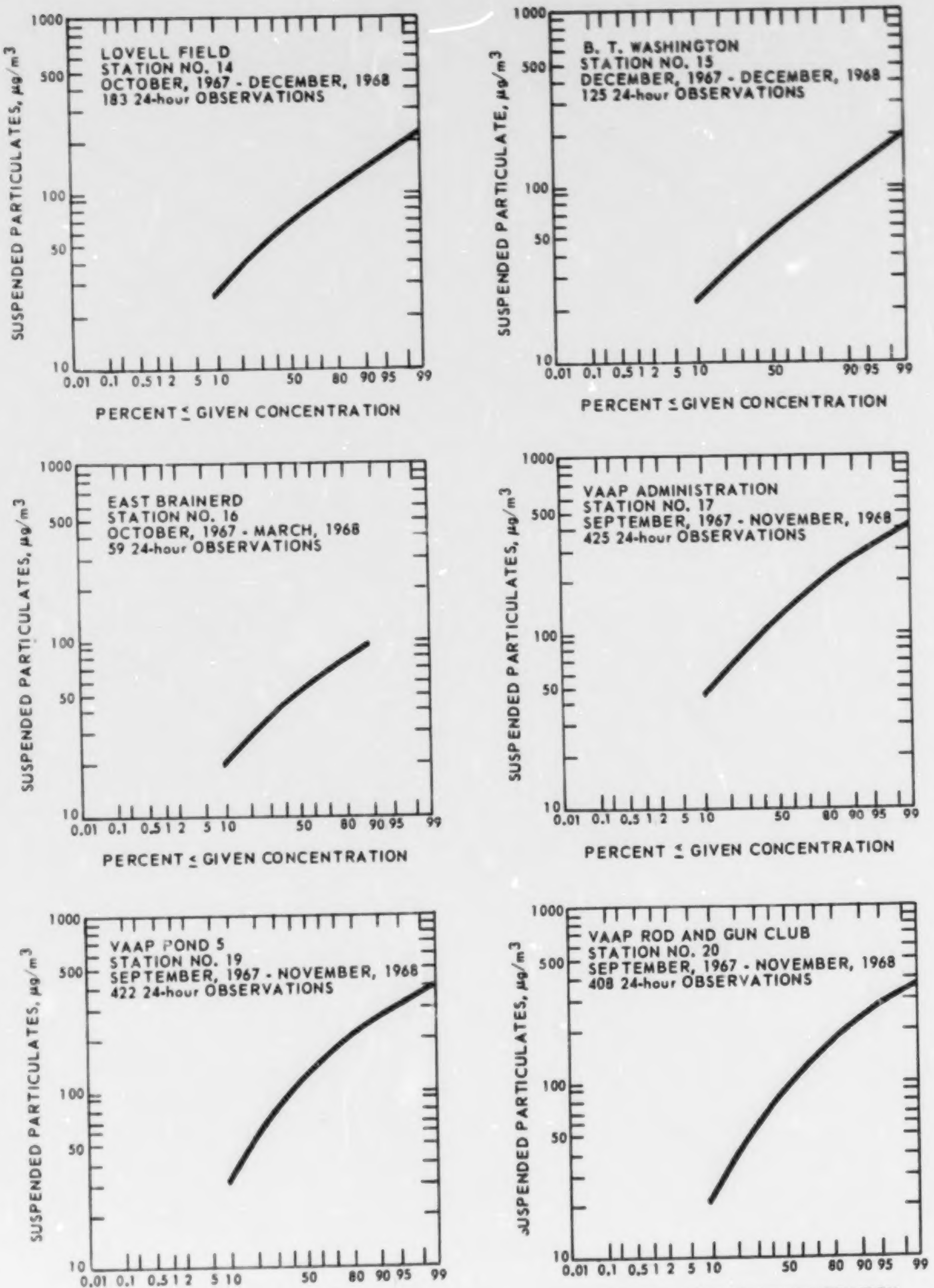


Figure C-3. Daily suspended particulate cumulative frequency distribution for sampling stations 14, 15, 16, 17, 19, and 20.

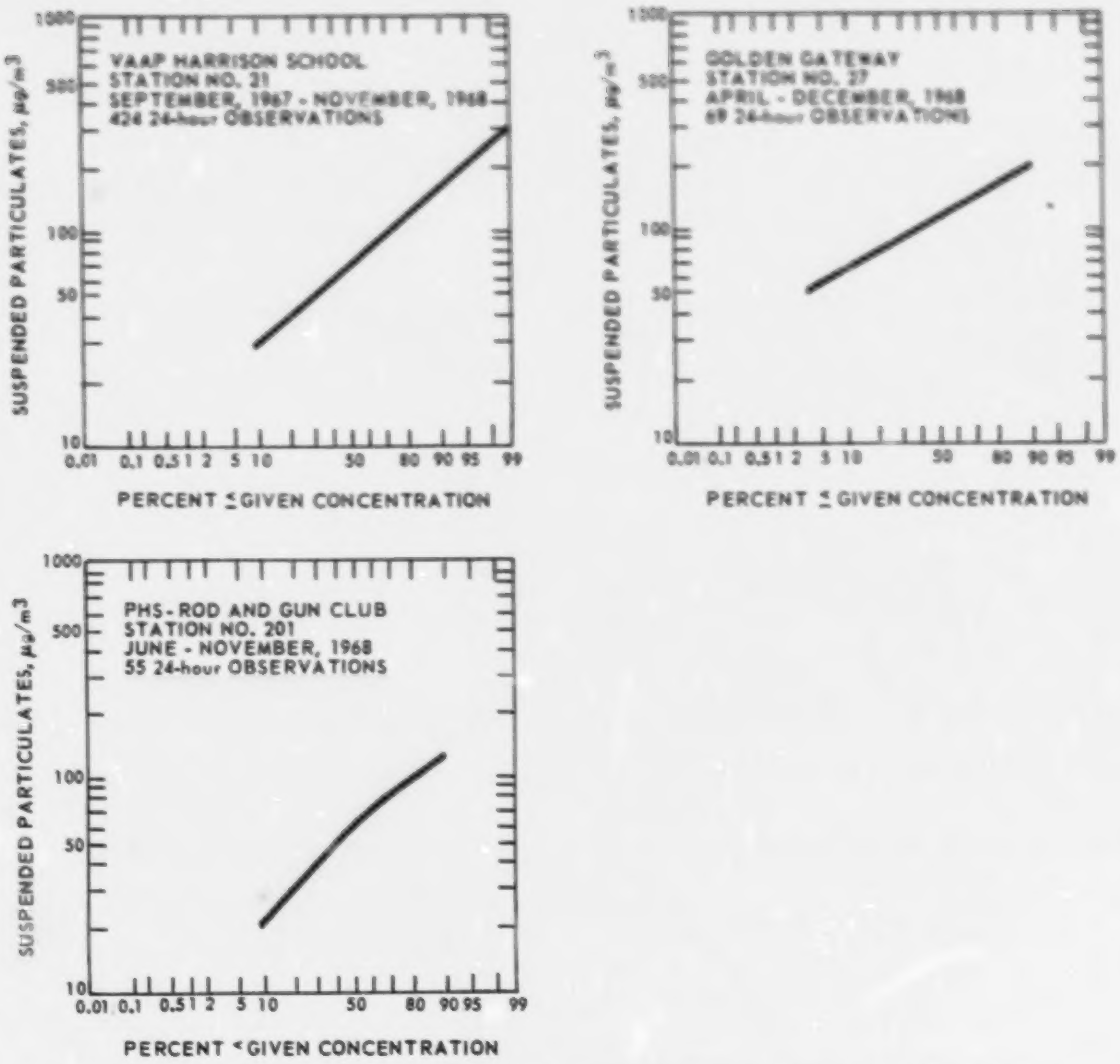


Figure C-4. Daily suspended particulate cumulative frequency distribution for sampling stations 21, 27, and 201.

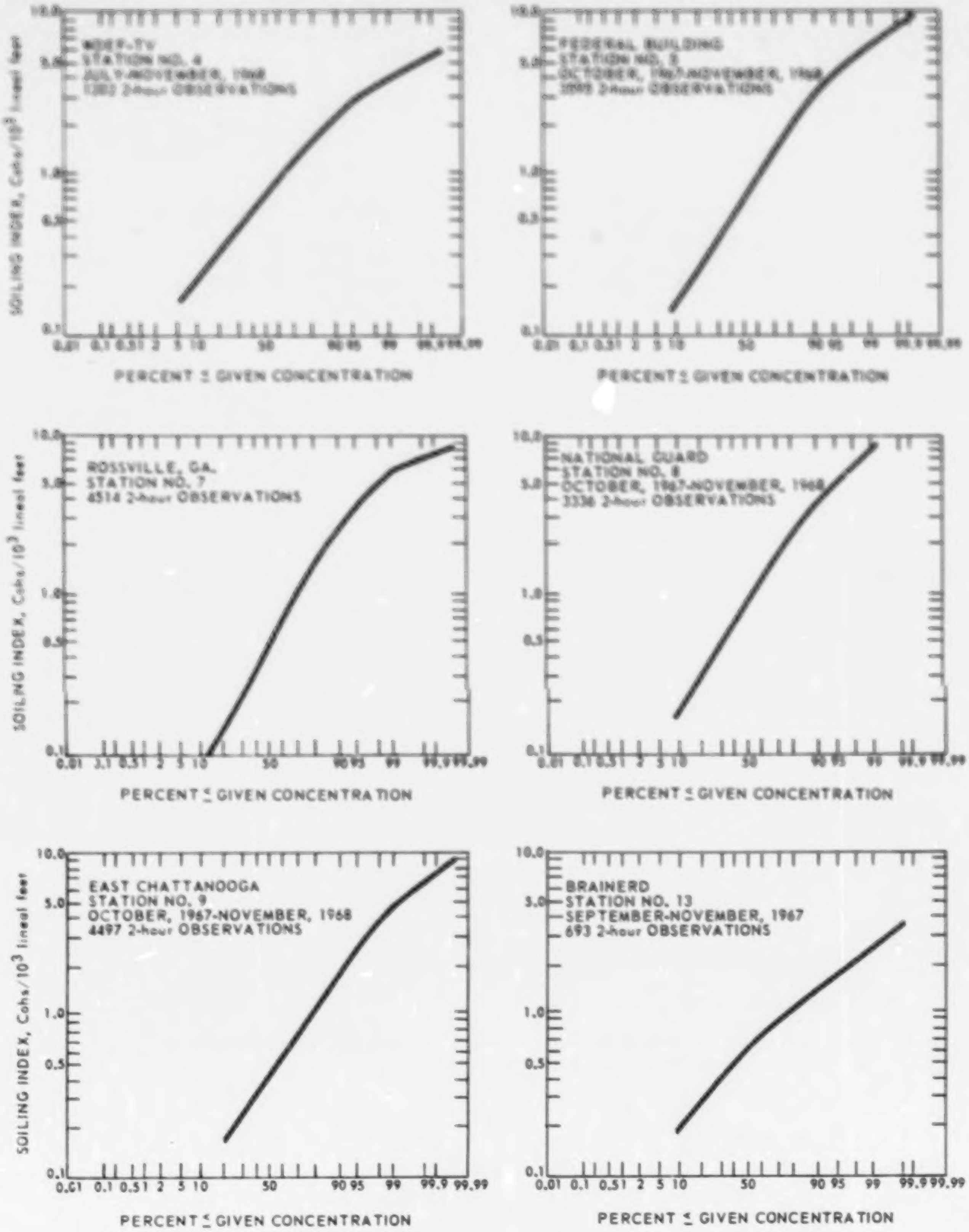


Figure C-5. Soiling index cummulative frequency distribution for sampling stations 4, 5, 7, 8, 9, and 13.

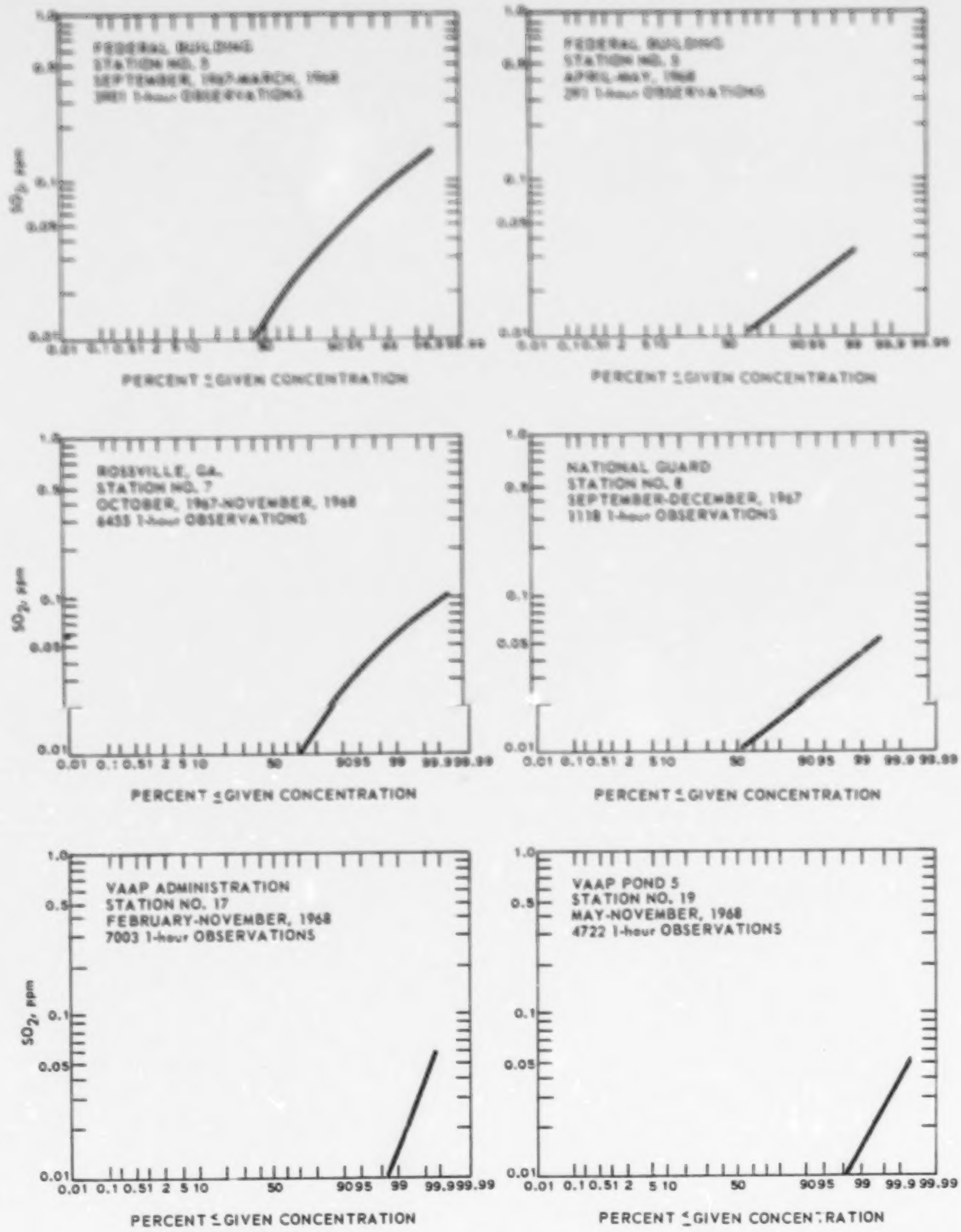


Figure C-6. One-hour average SO_2 cummulative frequency distribution for sampling stations 5, 7, 8, 17, and 19.

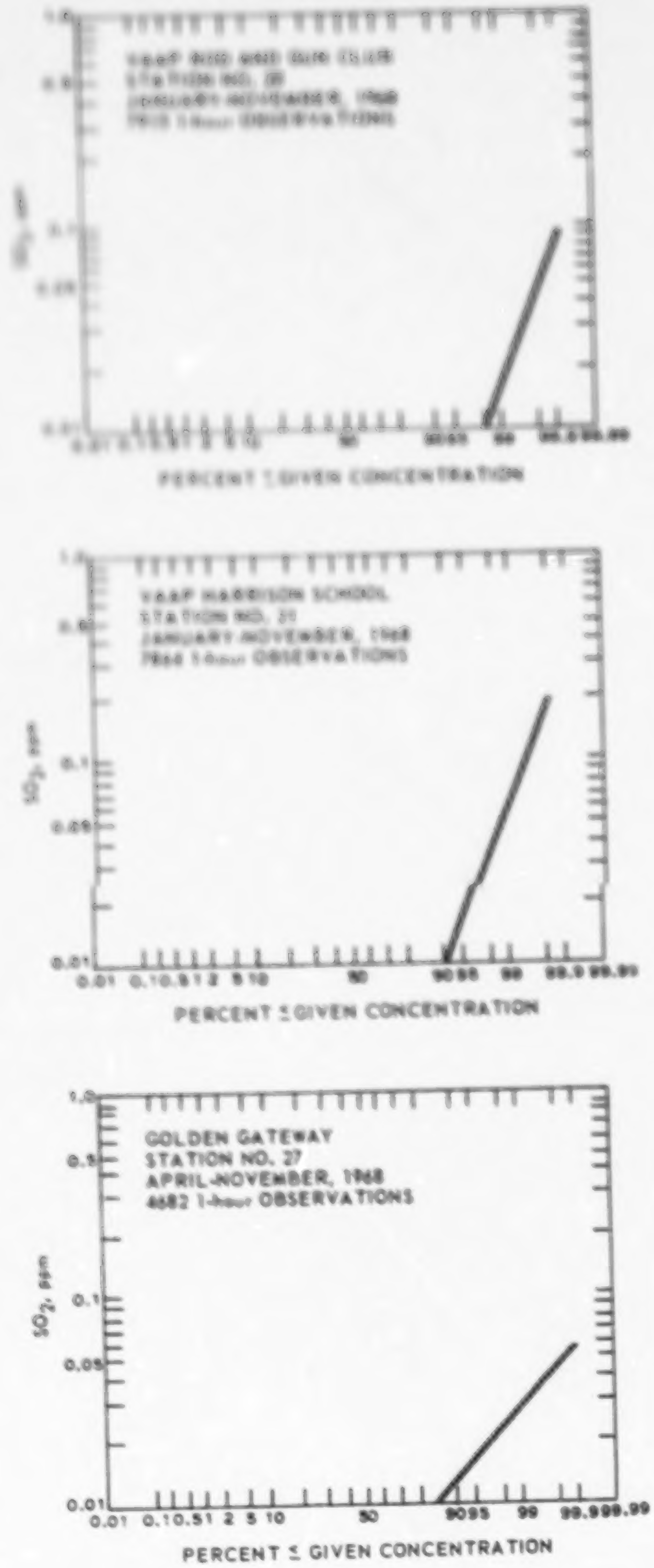


Figure C-7. One-hour average SO_2 cummulative frequency distribution for sampling stations 20, 21, and 27.

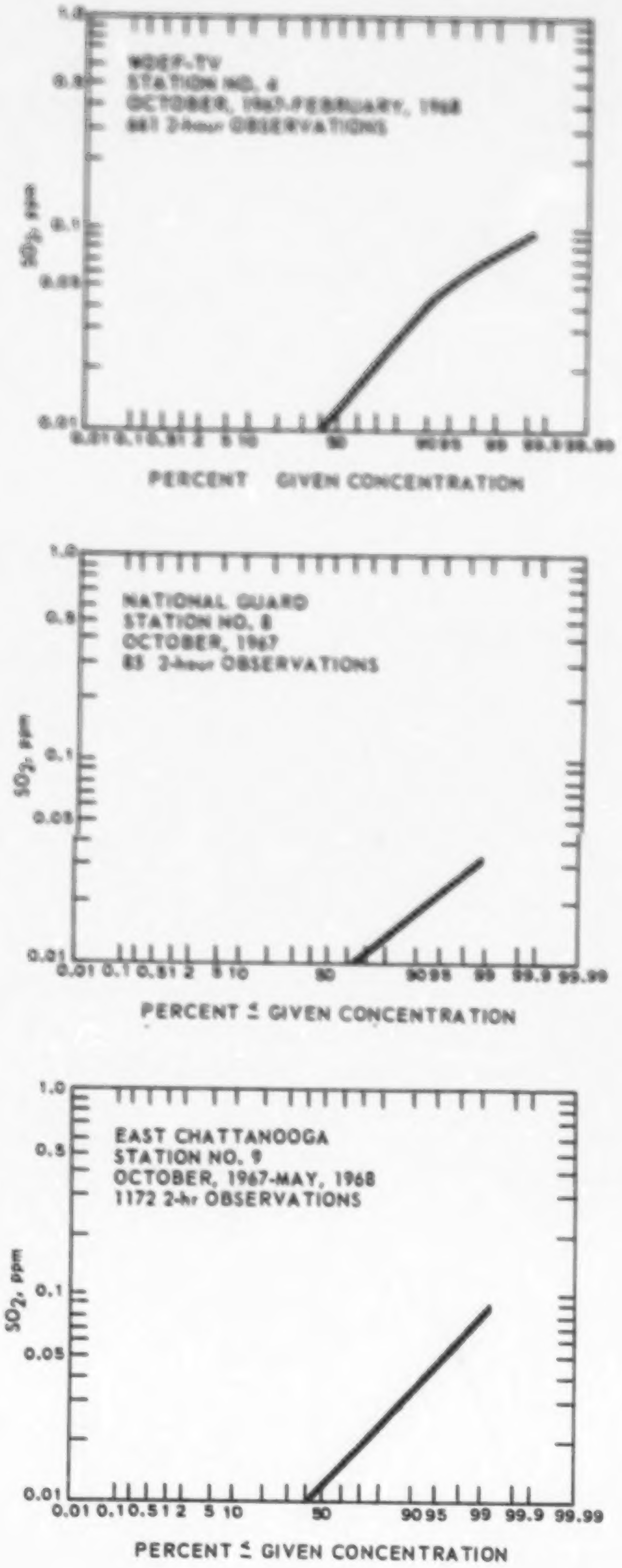


Figure C-8. Two-hour average SO_2 cummulative frequency distribution for sampling stations 4, 8, and 9.

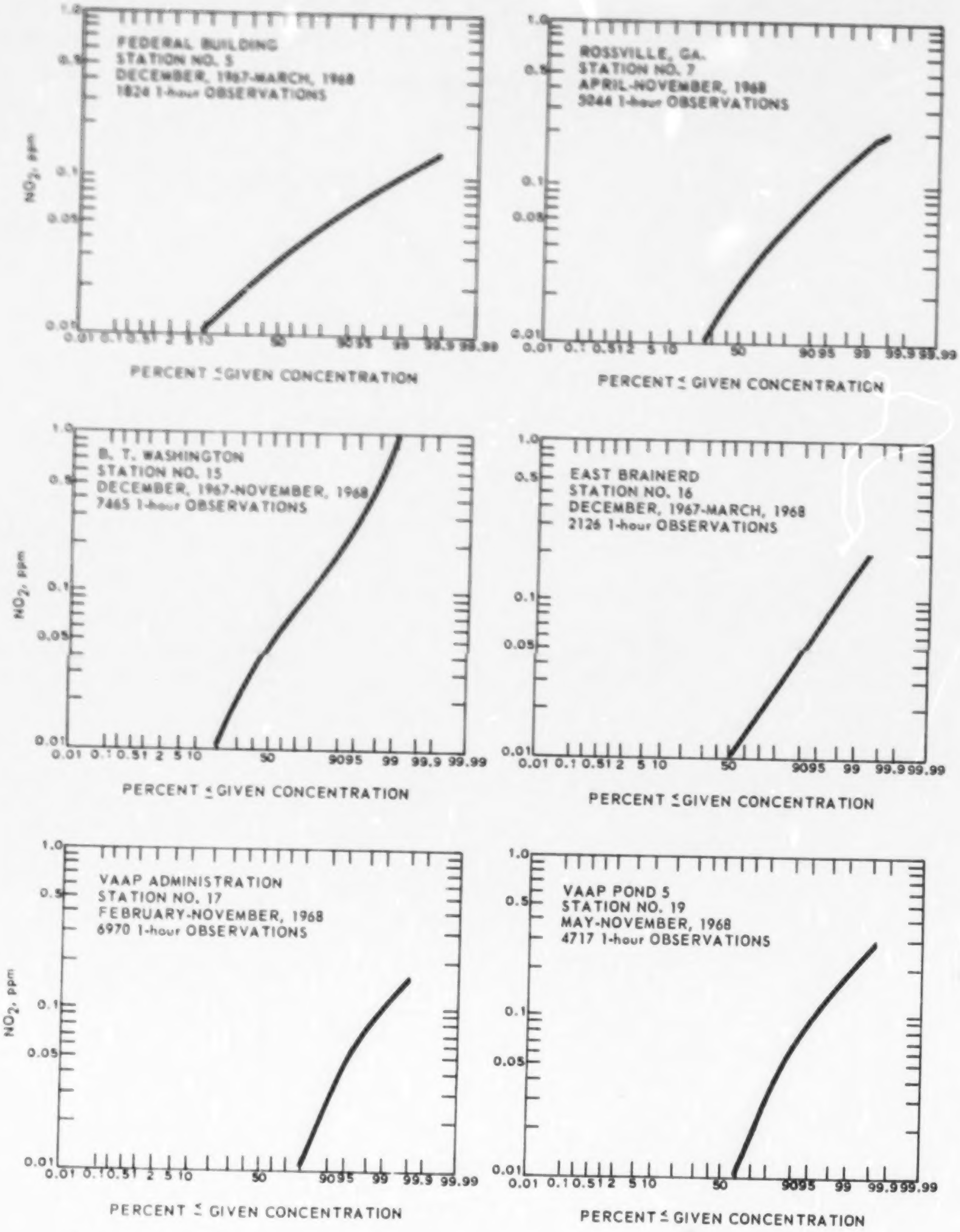


Figure C-9. Hourly average NO_2 cummulative frequency distribution for sampling stations 5, 7, 15, 16, 17, and 19.

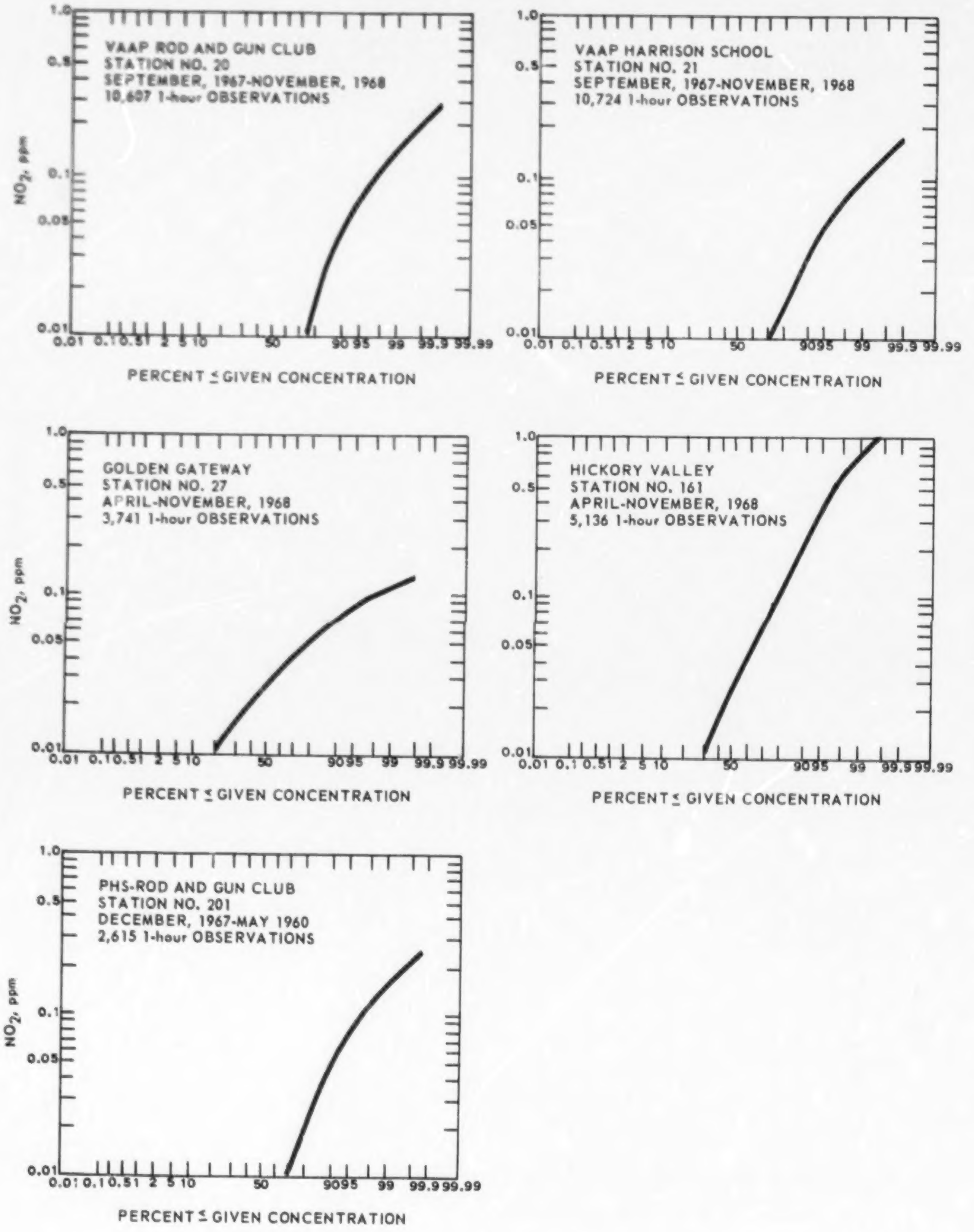


Figure C-10. Hourly average NO_2 cummulative frequency distribution for sampling stations 20, 21, 27, 161, and 201.

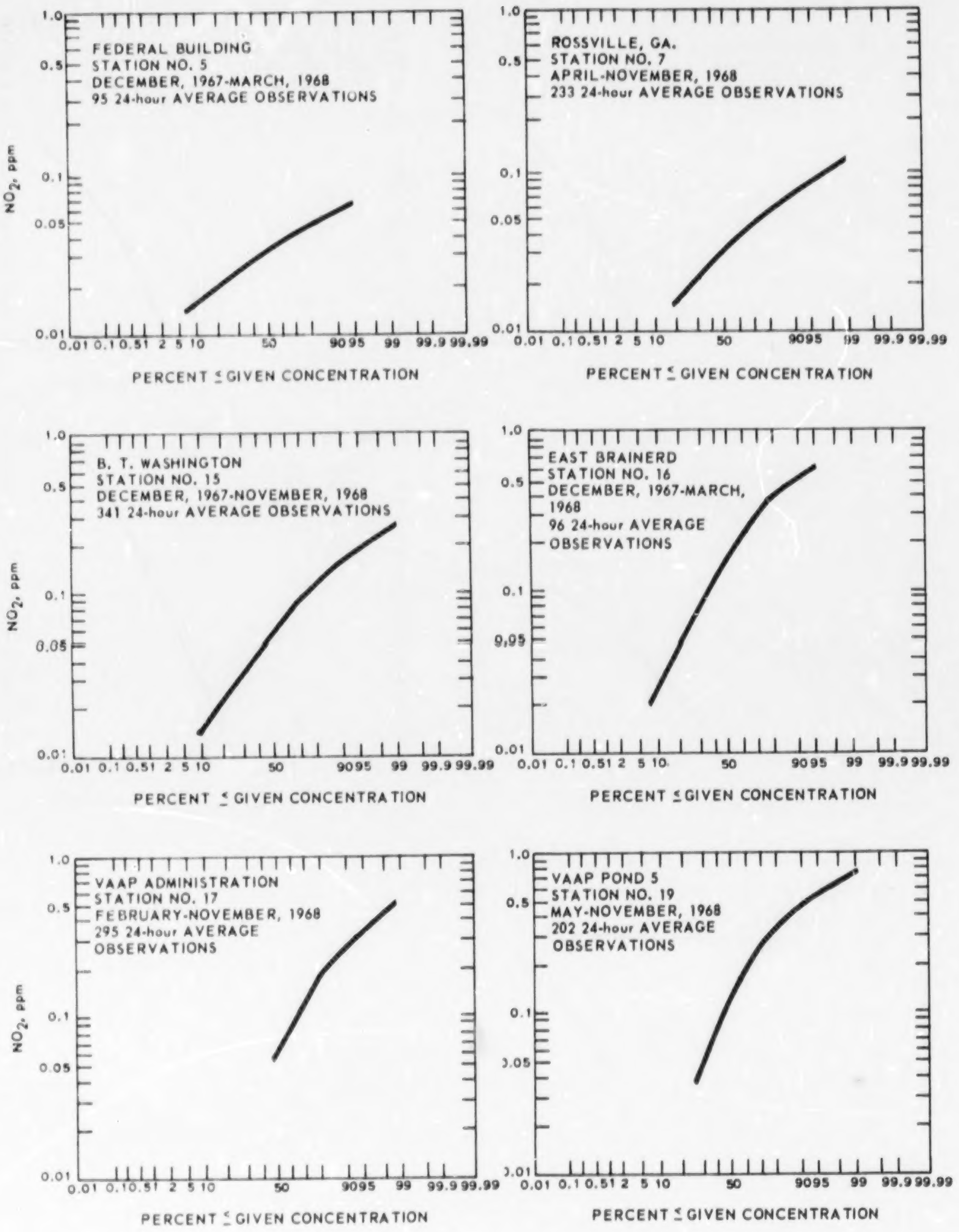


Figure C-11. Daily average NO_2 cummulative frequency distribution for sampling stations 5, 7, 15, 16, 17, and 19.

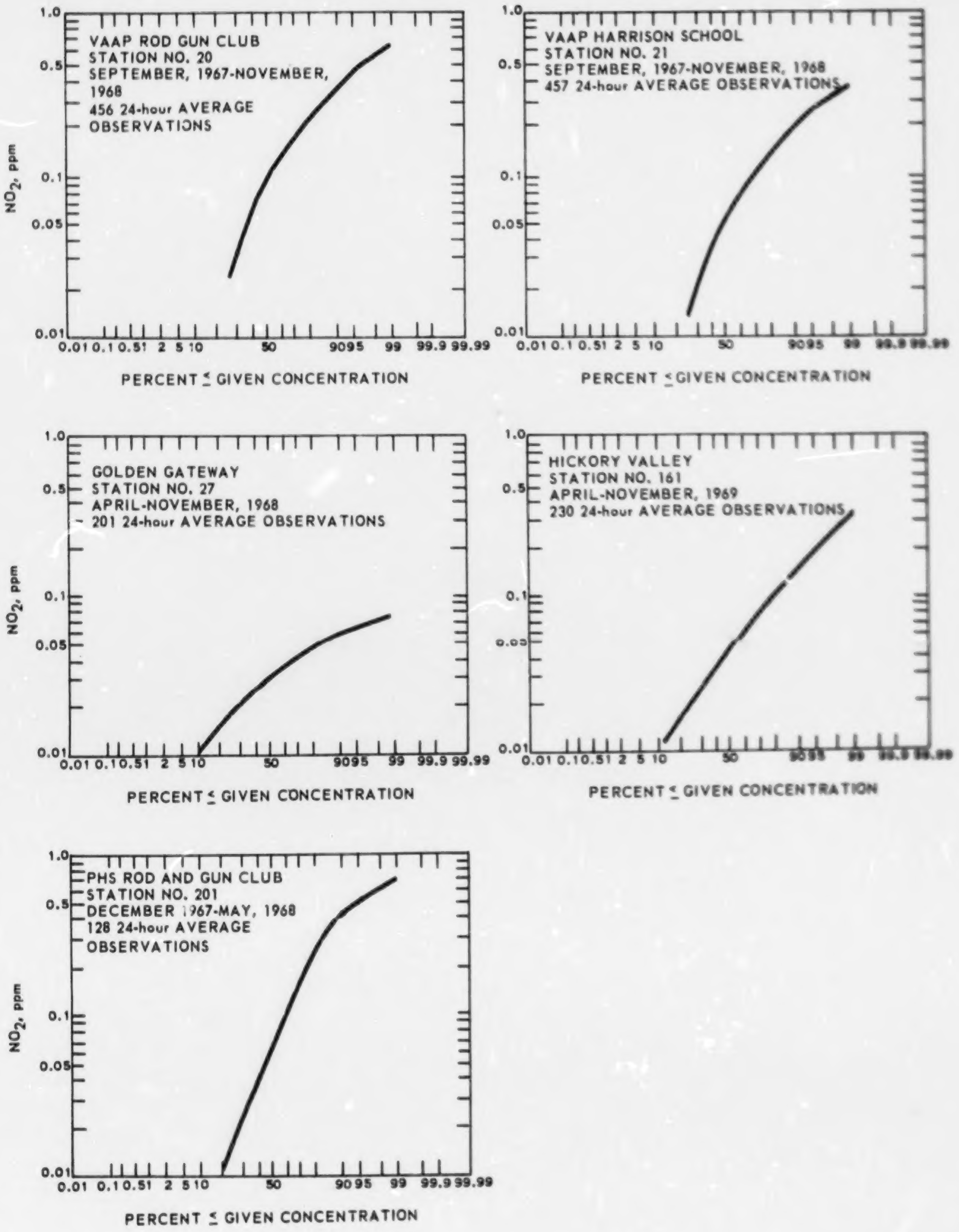


Figure C-12. Daily average NO_2 cummulative frequency distribution for sampling stations 20, 21, 27, 161, and 201.

APPENDIX D. EMISSION INVENTORY PROCEDURE

Both area and point sources were considered when compiling the emission inventory for the Chattanooga area. Emissions for point sources were calculated from source test results or material balance information, when available. When such information was not available, emissions were calculated by applying emission factors to fuel quantities, refuse quantities, and production rates that were obtained by questionnaires, plant visits, or published information. In some instances where no data could be obtained, emissions were based upon engineering estimates by NAPCA and the Chattanooga Bureau of Air Pollution Control personnel.

Because of their vast numbers, area sources contribute an important part to the total emissions; they include all mobile sources, most medium to small residential, commercial and governmental sources, and small industrial sources. Since individual contacts for each source were impossible, estimates were based on information such as: (1) traffic volume counts, (2) census estimates of population, dwelling units, manufacturing, and commercial operations, and (3) fuel usage information. Emissions were calculated directly from the fuel input records for both mobile and stationary sources.

Factors used to calculate pollutant emissions may be found in publications such as:

1. Duprey, R. L. Compilation of Air Pollutant Emission Factors. USDHEW, PHS, NAPCA. Public Health Service Publication No. 999-AP-42. Raleigh, N. C. 1968.

2. Procedure for Conducting Comprehensive Air Pollution Surveys. New York State Department of Health, Bureau of Air Pollution Control Services. Albany, New York. August 18, 1965.

D.1 STATIONARY FUEL COMBUSTION

Bituminous coal, distillate and residual fuel oils, and natural gas are the only fuels used in significant quantities in the study area. Fuel sources were listed as residential, commercial and governmental, and industrial. Fuel totals for the area were determined by various methods, depending on the fuel type and source category. Overall totals were obtained from local fuel dealers, the Chattanooga Gas Company, and National publications:

1. Bituminous Coal and Lignite Distribution, Calendar Year 1967. U.S. Department of the Interior. Bureau of Mines. March 1968.

2. Shipments of Fuel Oil and Kerosine in 1967. Fuel Oil Shipments Annual. U.S. Department of the Interior, Bureau of Mines. August 1968.

3. Minerals Yearbook, Volume II, 1962 and 1964. U.S. Department of the Interior, Bureau of Mines. 1964.

4. Fuels and Electric Energy Consumed in Manufacturing Industries. U.S. Department of Commerce, 1962. Census of Manufacturers, 1963.

D.1.1 Residential Fuel

Fuel consumption by residential sources was calculated on the basis of population, number of dwelling units, and relative use of coal versus oil versus natural gas found in:

1. Census of Population and Housing. U.S. Department of Commerce, Bureau of Census, Washington, D. C. PHS (1). 1960.
2. Domestic Heating Fuel in Certain Standard Metropolitan Statistical Areas Tabulated by Census Tract. U.S. Department of Commerce, Census of Housing, Washington, D. C. 1960.
3. Census of Housing. Tennessee HC (1)-44 and Georgia HC (1)-12. U.S. Department of Commerce, Bureau of Census, Washington, D. C. 1960.
4. Census of Population. Tennessee PC (1)-44B and Georgia PC (1)-12B. U.S. Department of Commerce, Bureau of Census, Washington, D. C. 1960.

Smaller, one or two family dwellings were assumed to use distillate fuel oil, bituminous coal, or natural gas. All-electric homes were exempted from the study, and large apartment complexes and hotels were placed in the commercial category.

The quantity of fuel used by each dwelling unit was based on the number of Btu's of heat required for an average 4.7-room dwelling unit and a record of 3397 degree-days for the study area in 1968. See Appendix C of:

> Rapid Survey Technique for Estimating Community Air Pollution Emission. U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio. NAPCA Publication No. 999-AP-29, Environmental Health Series. October 1966.

D.1.2 Commercial and Governmental Fuel

Large commercial, institutional, and governmental buildings were surveyed by questionnaire. Typical information obtained was: (1) combustion equipment type, (2) quantity and quality of fuel, and (3) existing control equipment and efficiency.

The fuel used by commercial and governmental establishments was apportioned to the emission zones based on area- and land-use information, and U.S. Geological Survey topographic maps. Emission factors were then applied to these fuel quantities to obtain pollutant emissions.

D.1.3 Industrial Fuel

Manufacturing concerns considered possible sources of air pollution were contacted by personal interview and/or questionnaire. Fuel data and process emissions were determined and recorded in the emission zone corresponding to the location of each facility.

State-wide data for industrial use of oil and coal were obtained from:

1. Minerals Yearbook. Volume II, 1962 and 1964. U.S. Department of Interior, Bureau of Mines. 1964.
2. Fuels and Electric Energy Consumed in Manufacturing Industries 1962. Department of Commerce. Washington, D. C. 1963.

Natural gas usage by industrial consumers was obtained from the Chattanooga Gas Company. Fuel consumption at stationary sources in the area is contained in Table D-1. Emission factors were applied to the fuel quantities to obtain pollutant emissions for the area (Tables D-2 through D-6).

Table D-1. CHATTANOOGA METROPOLITAN AREA FUEL CONSUMPTION, 1968

	Coal, tons	Fuel oil, gal		Gas, 10^6 cu ft	
Source	Bituminous	Distillate	Residual	Natural	Process
Hamilton County					
Industrial	157.283	816.000	1.822.000	15.470	2,043
Commercial-government	15.723	169.000	-	1.568	-
Resident	38.322	3,646.000	-	1.178	-
Total	211.328	4.631.000	1.822.000	18.216	2.043
Walker County					
Industrial	798	28.000	406.000	508	-
Commercial-government	729	7.000	-	81	-
Resident	12.718	1.319.000	-	91	-
Total	14.245	1.354.000	406.000	680	-
Catoosa County					
Industrial	533	11.000	32.000	144	-
Commercial-government	204	2.000	-	23	-
Resident	1.551	169.000	-	5	-
Total	2.288	182.000	32.000	172	-
Area total					
Industrial	158.614	855.000	2.260.000	16.122	2.043
Commercial-government	16.656	178.000	-	1.672	-
Resident	52.591	5.134.000	-	1.274	-
Total study	227.861	6.167.000	2.260.000	19.068	2.043

D.2 MOBILE SOURCES

D.2.1 Aircraft

The pollutants emitted from aircraft operations were estimated from data supplied by authorities at Lovell Field. These data included numbers of take-offs and landings by all types of private and commercial planes. Emissions were calculated by using factors for aircraft flights, considering the type and number of engines per plane.

Table D-2. CHATTANOOGA METROPOLITAN AREA STATIONARY FUEL COMBUSTION EMISSIONS, CARBON MONOXIDE 1968
(tons/yr)

Source	Coal	Fuel oil		Gas		County totals
	Bituminous	Distillate	Residual	Natural	Process	
Hamilton County						
Industrial	238	-	1	1	-	240
Commercial-government	393	-	-	-	-	393
Residential	958	4	-	-	-	962
Total	1,589	4	1	1	-	1,595
Walker County						
Industrial	1	-	-	-	-	1
Commercial-government	18	-	-	-	-	18
Residential	318	1	-	-	-	319
Total	337	1	-	-	-	338
Catoosa County						
Industrial	1	-	-	-	-	1
Commercial-government	5	-	-	-	-	5
Residential	39	-	-	-	-	39
Total	45	-	-	-	-	45
Area total						
Industrial	240	-	1	1	-	242
Commercial-government	416	-	-	-	-	416
Residential	1,315	5	-	-	-	1,320
Total study	1,971	5	1	1	-	1,978

Table D-3. CHATTANOOGA METEOPOLITAN AREA STATIONARY FUEL COMBUSTION EMISSONS, PARTICULATE 1968
(tons/yr)

Source	Coal	Fuel oil		Gas		County totals
	Bituminous	Distillate	Residual	Natural	Process	
Hamilton County						
Industrial	2,842	5	19	139	18	3,023
Commercial-government	197	1	-	15	-	213
Residential	192	15	-	11	-	218
Total	3,231	21	19	165	18	3,454
Walker County						
Industrial	26	-	5	5	-	36
Commercial-government	9	-	-	1	-	10
Residential	64	5	-	1	-	70
Total	99	5	5	7	-	116
Catoosa County						
Industrial	17	-	-	1	-	18
Commercial-government	3	-	-	-	-	3
Residential	8	1	-	-	-	9
Total	28	1	-	1	-	30
Area total						
Industrial	2,885	5	24	145	18	3,077
Commercial-government	209	1	-	16	-	226
Residential	264	21	-	12	-	297
Total study	3,358	27	24	173	18	3,600

Table D-4. CHATTANOOGA METROPOLITAN AREA STATIONARY FUEL COMBUSTION EMISSIONS, SULFUR OXIDES 1968
(tons/yr)

	Coal	Fuel oil		Gas		
Source	Bituminous	Distillate	Residual	Natural	Process	County totals
Hamilton County						
Industrial	4,460	20	209	1	280	4,970
Commercial-government	444	4	-	-	-	448
Residential	619	35	-	-	-	654
Total	5,523	59	209	1	280	6,072
Walker County						
Industrial	23	-	58	-	-	81
Commercial-government	21	-	-	-	-	21
Residential	205	13	-	-	-	218
Total	249	13	58	-	-	320
Catoosa County						
Industrial	15	-	5	-	-	20
Commercial-government	6	-	-	-	-	6
Residential	25	2	5	-	-	27
Total	46	2	5	-	-	53
Area total						
Industrial	4,498	20	272	1	280	5,071
Commercial-government	471	4	-	-	-	475
Resident	849	50	-	-	-	899
Total study	5,818	74	272	1	280	6,445

Table D-5. CHATTANOOGA METROPOLITAN AREA STATIONARY FUEL COMBUSTION EMISSIONS, NITROGEN OXIDES 1968
(tons/yr)

	Coal	Fuel oil		Gas		
Source	Bituminous	Distillate	Residual	Natural	Process	County totals
Hamilton County						
Industrial	1,569	31	65	1,657	219	3,541
Commercial-government	62	6	-	94	-	162
Residential	153	22	-	68	-	243
Total	1,784	59	65	1,819	219	3,946
Walker County						
Industrial	8	1	15	55	-	79
Commercial-government	3	-	-	5	-	8
Residential	51	8	-	5	-	64
Total	62	9	15	65	-	151
Catoosa County						
Industrial	5	-	1	15	-	21
Commercial-government	1	-	-	1	-	2
Residential	6	1	-	-	-	7
Total	12	1	1	16	-	30
Area total						
Industrial	1,582	32	81	1,727	219	3,641
Commercial-government	66	6	-	100	-	172
Residential	210	31	-	73	-	314
Total study	1,858	69	81	1,900	219	4,127

Table D-6. CHATTANOOGA METROPOLITAN AREA STATIONARY FUEL COMBUSTION EMISSIONS, HYDROCARBONS 1968

(tons/yr)

Source	Coal	Fuel oil		Gas		County totals
	Bituminous	Distillate	Residual	Natural	Process	
Hamilton County						
Industrial	76	-	-	-	-	77
Commercial-government	78	-	-	-	-	78
Residential	192	5	-	-	-	197
Total	346	5	1	-	-	352
Walker County						
Industrial	-	-	-	-	-	-
Commercial-government	4	-	-	-	-	4
Residential	64	2	-	-	-	66
Total	68	2	-	-	-	70
Catoosa County						
Industrial	-	-	-	-	-	-
Commercial-government	1	-	-	-	-	1
Residential	8	-	-	-	-	8
Total	9	-	-	-	-	9
Area total						
Industrial	76	-	1	-	-	77
Commercial-government	83	-	-	-	-	83
Residential	264	7	-	-	-	271
Total study	423	7	1	-	-	431

D. 2. 2 Railroads

Fuel consumption information was obtained from the three Hamilton County companies. Calculations were limited to switching operations since fuel consumption outside of switching yards was not found to be a major source of pollution.

D. 2. 3 Automobiles

Automobile emission estimates were based on gasoline consumption and automobile vehicle-miles traveled in the area. Traffic counts for major streets were obtained from city and county traffic offices, then transposed into vehicle-miles per area grid, and used to apportion gasoline quantities to each grid according to the percentage of the total vehicle-miles traveled in the grid. Emission factors were applied to these grid fuel quantities to give total emissions from automotive exhaust per grid.

D. 2. 4 Diesel Vehicles

The emissions from diesel-operated motor vehicles were calculated by applying emission factors to the quantity of diesel fuel consumed in each county. They were distributed on a percentage basis along the commercial, industrial and major arterial streets in each county. Bus routes, shopping areas, and waterfront locations were also considered in the distribution. Table D-7 contains the 1968 inventory of emissions from mobile sources.

D.3 SOLID WASTE DISPOSAL

The amount of refuse disposed of in the study area was estimated on the basis of information gained from supervisory personnel at municipal dumps and landfills,

Table D-7. CHATTANOOGA METROPOLITAN AREA MOBILE SOURCE EMISSIONS, 1968

Location and pollutant	Gasoline, 10^3 gal/yr	Gasoline vehicles, tons/yr	Diesel fuel, 10^3 gal/yr	Diesel vehicles, tons/yr	Number flights per year	Aircraft, tons/yr	RR diesel fuel, 10^3 gal/yr	Railroads, tons/yr	Total emissions, tons/yr
Hamilton County	115,000		3,335		59,781		441		
Particulate		690		183		34		94	1,001
SO_x		518		67		-		35	620
NO_x		6,497		370		142		190	7,199
HC		14,621		227		504		117	15,469
CO		125,637		100		2,454		51	128,242
Walker County	16,400		37		-		-		
Particulate		98		2		-		-	100
SO_x		74		1		-		-	75
NO_x		927		4		-		-	931
HC		2,084		2		-		-	2,086
CO		17,917		1		-		-	17,918
Catoosa County	6,500		283		-		-		
Particulate		39		16		-		-	55
SO_x		29		6		-		-	35
NO_x		367		31		-		-	398
HC		826		19		-		-	845
CO		7,101		9		-		-	7,110
Study total	137,900		3,655		59,781		441		
Particulate		827		201		34		94	1,156
SO_x		621		74		-		35	730
NO_x		7,791		405		142		190	8,528
HC		17,531		248		504		117	18,400
CO		150,655		110		2,454		51	153,270

and of the National average of 4.5 pounds per capita per day for domestic refuse generated, data found in:

> Waste Management and Control. National Academy of Sciences, National Research Council. Washington, D. C. Publication No. 1400. 1966.

All solid waste generated in the City of Chattanooga was assumed to have been collected and disposed of in the city dump or in private incinerators. Of the uncollected solid wastes generated in Hamilton County, outside of Chattanooga, and in Walker and Catoosa Counties, 45 percent was assumed to have been burned in backyards and 55 percent disposed of by landfilling. The solid waste disposal emissions are listed by county and pollutant in Table D-8.

Table D-8. CHATTANOOGA METROPOLITAN AREA, SOLID WASTE DISPOSAL 1968
(tons/yr)

	Land fill	Backyard burning	Open burning dump	On site incineration	Total
Hamilton County	128,260	31,750	38,500	17,110	215,620
Particulate		320	905	55	1,280
SO_x		20	24	12	56
NO_x		175	210	21	406
HC		2,313	1,540	34	3,887
CO		951	1,640	229	2,820
Walker County	23,850	16,350	3,590	0	43,790
Particulate		160	84	-	244
SO_x		110	2	-	12
NO_x		90	20	-	110
HC		1,190	140	-	1,330
CO		490	150	-	640
Catoosa County	11,700	8,000	0	0	19,700
Particulate		80	-	-	80
SO_x		5	-	-	5
NO_x		44	-	-	44
HC		582	-	-	582
CO		240	-	-	240
Study total	163,810	56,100	42,090	17,110	279,110
Particulate		560	989	55	1,604
SO_x		35	26	12	73
NO_x		309	230	21	560
HC		4,805	1,680	34	5,799
CO		1,681	1,790	229	3,700

D.4 PROCESS SOURCES

Emissions from industrial processes were determined from production rates, raw material consumption, exhaust gas volumes, and stack test data, when available. Sources to be investigated were selected from:

> Manufacturers Directory Chattanooga and Tri-State Area, 1968-1969. Industrial Development Committee Greater Chattanooga Chamber of Commerce, Chattanooga, Tennessee. 1969.

Hydrocarbon losses from dry cleaning and surface coating were estimated on a per capita basis for the area. Hydrocarbon losses from gasoline handling and storage were based on total gasoline consumption in the area. This estimate took into account losses while filling tank trucks from storage tanks, service station storage tanks from trucks, and automobile gasoline tanks from service station pumps.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970—436-414/81